A TEXTBOOK
OF
STERILIZATION

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By

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Introductory

IT IS well for every individual whose work or interests center about the surgery to read thoughtfully from time to time the experiences of early investigators which relate to the terrible infections prevalent in all hospitals prior to the introduction of antiseptic surgery.

The death rate in some of those earlier hospitals ran as high as 60 to 80 percent. The individual compelled to undergo surgery was actually safer at home than in the hospital, where he was almost certain to contract infection. At home he was relatively safe. In some cases entire buildings were burned down to rid the community of the polluted material.

Joseph Lister experienced this sort of thing and, knowing nothing of bacteria, he developed a sanitary system in which by infinitely painstaking methods, he pretty largely eliminated infections, using carbolic acid instead of mechanical sterilizers.

We have the advantage of knowing the cause of infections and we have machines which will destroy the most resistant microbes, but at times we grow careless, or develop a false sense of security because average sanitary precautions and average, but somewhat lax, sterilization procedures seem to meet average requirements. Or perhaps we assume that God given, American right to take chances.

Whatever the reason may be, now and again the unusual condition takes its toll, infections do occur—and there is a mad scramble to fix the blame. Too infrequently the sterilization processes get the blame as a thorough-going survey of common performances will indicate. The average margin of safety is non-existent or too small to cover the unusual requirement.

For the sake of emphasis I repeat that we know how to destroy the most resistant pathogenic spores. There is nothing very difficult involved. There must be adequate equipment and there must be definite knowledge of the fundamentals. Without these, any sterilizing performance will include an element of danger. That we do not always provide for sterilization that is adequate for the unusual occasion is a criticism of methods, a sacrifice at the altar of speed perhaps, or unjustified economy, or careless evasion of specific needs.

By combining engineering data with the enlightening experiences which have come from more than twenty years close association with sterilization problems, it has been possible to formulate this

text. I sincerely hope that this contribution will aid in some measurable degree toward the standardization of systems of sterilizing which completely eliminate the chance-taking elements.

WEEDEN B. UNDERWOOD.

Written at
Gananoque, Ontario,
July 28, 1934.

INTRODUCTORY TO THE SECOND EDITION

Time marches on and with the years our fund of useful information about sterilization has grown. With only minor exceptions we have found no justification for change in the original text as published in 1934. We have been able to clarify some of the text and in a number of instances better illustrations have become available. Considerable new material has been included.

Throughout this text it has been our aim to present material that will be of practical, everyday value in establishing standards for sterilization, expressed in easily understood terms. Literature pertaining to the subject in general is rather pitifully lacking, which accounts for the very infrequent reference to bibliography. To a large degree it has been necessary to investigate various practices which have been established, to analyze the results by careful tests and to select by this method those processes which have most practically met requirements.

Much of our investigative work has been conducted in the larger institutions but we have not overlooked the smaller hospitals and their peculiar problems. In particular I am deeply indebted to the following institutions for their cooperation and especially for their generous encouragement to continue this type of research:

JOHNS HOPKINS HOSPITAL, Baltimore.
HOSPITAL OF THE UNIVERSITY OF PENNSYLVANIA, Philadelphia.
WESTERN RESERVE UNIVERSITY HOSPITALS, Cleveland.
STRONG MEMORIAL HOSPITAL, University of Rochester.
JEFFERSON HOSPITAL, Philadelphia.

WEEDEN B. UNDERWOOD.

CHAPTER I

The Destructive Factor in Steam is Temperature—Not Pressure. Determination of Minimum Requirements.

One of the surprising facts clearly indicated by close contact with the people who actually use sterilizers as well as those who direct the work, is that in discussing sterilization, so few of them ever refer at all to (temperature) the one essential property of steam which has to do with the destruction of bacteria and spores.

Nearly every operator assumes that the pressure of steam is the essential factor and that if pressure is maintained—the temperature, indicated for (pure steam) on most pressure gauges above the pressure readings, must necessarily follow.

Our purpose is to be helpful rather than merely critical, but to illustrate how much at variance generally accepted beliefs are to the facts, a series of rather typical tests will be described. The ten temperature curves shown on Fig. 1 were made in six prominent hospitals, with surgical supply sterilizers just as they were being used. The curves show the temperatures which were developed in the loads.

Every one of the sterilizers described was in good operating condition. Every one might have been operated with results similar to No. 1 curve. With only one exception was there any suspicion that the performance was not perfectly adequate. In one hospital serious infections had developed.

Records of these glaring inconsistencies are not presented to frighten but to explain the need of directing the efforts of surgical supervisors toward a logical method of training operators, and the establishment of systems of sterilizing which are amply safe and efficient, and in keeping with other supposedly precise details of surgery.

Steam Temperatures Required for Sterilization. One of the most difficult problems met in the attempt to define safe sterilization is to determine from any authoritative source exactly what temperature is needed for the destruction of the most resistant pathogenic spores so that temperature records and methods of controlling sterilizers can be discussed intelligently.

Writers on the subject in standard textbooks of bacteriology are vague. These texts invariably refer to results that can be secured by maintaining certain pressures for certain periods of time, without

in the slightest degree indicating what effect the character or size of the load may have on the results, and with only indefinite reference to temperatures. Pressure has nothing to do with the destruction of bacteria except that it is needed to produce the desired temperatures. Fifteen pounds pressure applied to a sterilizing chamber, even for a long period of time, might mean anything in temperature from 212 to 250 degrees F. depending upon the degree of air evacuation from the chamber. The period of exposure must always depend upon the size of the packs and their density. Fifteen minutes might be perfectly adequate for a light load, or 30 minutes might be altogether inadequate for a dense, heavily packed load—in the same sterilizer.

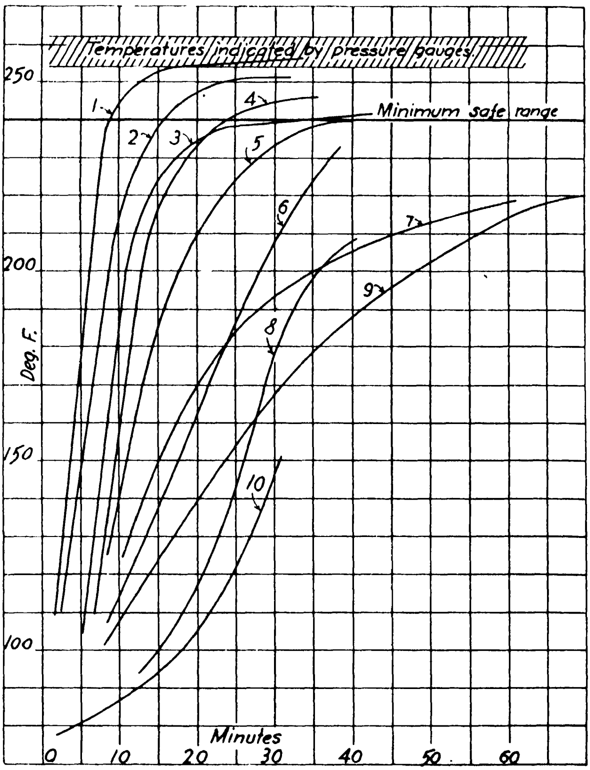


FIG. 1. These curves record the actual temperatures secured within the loads of ten typical surgical sterilizers operated under pressure, but with no measured regard for the degree of air elimination secured and consequent temperatures. The shaded area denotes the temperatures which were indicated by the pressure gauges for pure steam. Pressures were maintained at 17 to 22 pounds. The curves show the temperatures secured within the loads and the periods of exposure. The minimum safe range of temperature is also indicated.

Ford's Textbook of Bacteriology, 1927 edition, page 170, states: "Surgical dressings and bandages are best sterilized by steam under pressure. An exposure for 15 to 20 minutes to a pressure of 10 to 15 pounds usually suffices to render them free from bacteria."

Hiss-Zinsser's Textbook of Bacteriology, 1927 edition, page 70 states: "Exposure to steam under 15 pounds pressure for 15 to 20 minutes, is sufficient to kill all forms of bacterial life, including spores."

Neither of these typical statements about sterilization is specific about the degree of temperature attained in the mass undergoing sterilization, or about the size of the load. Both obviously refer to exceedingly light loads and perfect performance of the sterilizer in the detail of air elimination. Both (do) limit the maximum temperature requirements by the pressures specified. The greatest possible temperatures that could be secured in pure saturated steam at 10 to 15 pounds pressure, would be 240 to 250 degrees F. (115 to 121 degrees C.)

Determination of Minimum Requirements

To make an accurate determination of the minimum limits of saturated steam temperature requirements for surgical sterilization, a series of most unusual tests was made during the winter of 1933–34. Various capable bacteriologists were consulted, who agreed that spores of Cl. welchii (gas bacillus) and B. subtilis (hay bacillus) would be typical of the most heat resistant of any in the pathogenic group.

Upward of one hundred preliminary tests were made in which it was found without a single failure, that (moist) cultures of these organisms were destroyed in saturated steam at 220 degrees F. (105 degrees C.) in five minutes exposure. It was later found, however, that when these cultures were permitted to dry out for two or three days, they became more resistant, after which this temperature and period of exposure were not always adequate. Some of these cultures grew upon incubation.

A second series of tests was then carried out in which the cultures were prepared and allowed to dry in an open room for two to three weeks. More than sixty of these tests were then made, as nearly identical as physical conditions would permit, in each of which the dried cultures were subjected to saturated steam at 225 degrees F. (107 degrees C.), equivalent to slightly more than 4 pounds pure steam pressure, for five minutes. There was no single failure. No growths developed after prolonged incubation.

It may be interesting to note how these tests were made. Packs containing the cultures were loose rolls of gauze, approximately 12″

long and 3″ in diameter. A pledget of cotton was located in the center of the roll near each end, one infected with Cl. welchii, the other with B. subtilis. A thermocouple was located in the center of the roll for the determination of temperature.

For each group of tests, usually six to twelve packs per day, one pack was set aside to be used as a control. It was subjected to the same handling as the test packs except it was not put through the sterilizer. The purpose of the control was to indicate, by incubation, whether or not the cultures were alive. None of the control cultures in all the tests failed to grow profusely.

A sterilizer was arranged so that steam could be admitted to and discharged from the chamber with most unusual speed. Corresponding facility was arranged for rapid air elimination from the chamber. The total period for each test, including the five-minute interval for sterilizing and the time required for opening and closing the door, did not exceed ten to eleven minutes. By using this method, there was no appreciable period of time required for building up or reducing temperature.

These facts are submitted as evidence of the absolute minimum temperature requirements for an exposure period of 5 minutes. No attempt is made to define from this data, a sterilization performance based upon maintenance of temperature at 225 degrees F. We merely determine with some reasonable degree of accuracy by tests which were comparable to every day work in sterilizing, what the extreme low limit of temperature is for a very brief interval of exposure. By no means do we recommend attempt to sterilize at this range. Just as engineers always apply a safety factor in calculating strength of materials, so must a safety factor be applied here in sterilizing. We can, however, now read temperature curves such as Fig. 1 with some intelligence. Those sterilizers which produced temperatures in the loads in excess of 225 degrees F., even though some of them were highly inefficient, and were working far too close to the low limits for safety, were sterilizing. Those in which lower temperatures only were developed (curves 7–8–9–10) were not sterilizing, and these facts were substantiated by the actual experiences. Serious infections had occurred in the one hospital from which these curves were secured. None of the other hospitals had experienced any unusual difficulty.

It is our purpose to show that to attempt definition of surgical sterilization upon the basis of pressure maintained without measured regard for the temperature developed in the steam, leads to the discrepancies illustrated by temperature curves Fig. 1. If the sterilizing chamber is not properly evacuated of air, suitable temperatures cannot be attained in any reasonable period of time at least, and failures will occur. The one sure method of knowing the sterilizing quality

of the steam applied, regardless of the pressure, is to measure its temperature.

This can now be done. Precision sterilization is possible. Readers are urged to familiarize themselves thoroughly with the data contained in the following chapter, "Analysis of the functions of steam in sterilizing," before passing on to the more directly interesting details of loading and operation.

Tests by Dr. E. E. Ecker of Western Reserve University

I am permitted to quote the following from experiments conducted during March and April 1935 by Dr. E. E. Ecker of The Institute of Pathology and The University Hospitals, Western Reserve University, Cleveland, Ohio.

"In order to collect further data on the problem of efficient sterilization, bacteriological observations were made using four spore bearing organisms namely: B. subtilis, Cl. welchii, B. septicus, Cl. novyi (oedematiens).

"Four weeks old brain broth cultures of the organisms, free from vegetative cells, were spread over filter paper strips and allowed to dry at 37°C. The strips of paper containing the spores were introduced into the centers of surgical packs and the materials were exposed to steam temperatures varying from 215° F. to 250° F. at 5 degree intervals. Following exposure the strips of filter paper were removed with strict aseptic technique and introduced into brain broth tubes and incubated for two weeks. Unheated (control) strips gave growth within 48 hours.

"Temperatures inside the surgical packs were measured with a Leeds and Northrup Potentiometer with thermocouples inserted in the packs with points at the same location as the filter paper strips. The instrument was calibrated during the tests and found to be accurate within one half of one degree. A special sterilizer was used in which time required for building up temperature to the exposure range did not exceed 60 seconds. Equally rapid provision was made for exhaust of steam following exposure.

"It was found in the long series of experiments that the spores of Cl. novyi were the most resistant. They survived exposure of 5 minutes at 230° F. but were destroyed in 10 minutes at 230° F. The spores of B. septicus resisted temperature of 220° F. for 15 minutes but were destroyed in 5 minutes at 225° F. The spores of Cl. welchii survived exposure of 15 minutes at 215° F. but were destroyed at 220° F. in 5 minutes. Spores of B. subtilis were killed at 215° F. in 10 minutes."

Tests By Anson Hoyt, Robert L. Chaney and Korine Cavell of University of Southern California

Reference is made to the article which appeared in the December 1938 Journal of Bacteriology by the above investigators. Analysis of this article indicates that typical resistant spores (surgically significant) such as Cl. oedematiens, Cl. welchii, Cl. tetani, were destroyed (in direct contact with steam) as follows:

6 lbs. saturated steam (110° C. or 230° F.) in 10 min. exposure.
10 lbs. saturated steam (115° C. or 240° F.) in 4 min. exposure.
15 lbs. saturated steam (121° C. or 250° F.) in 1 min. exposure.

We have used the above data throughout this text as a background for the establishment of various exposure periods, including always a suitable factor of safety, usually in the form of considerable additional time greater than the minimum requirements indicate. It is quite obvious that use of temperature higher than 250° F. (121° C.) is of little value because, in direct contact with steam, sterilization occurs almost instantly at this range.

It is well to point out that there are certain non-pathogenic spore forms in which the bacteriologist is interested, which are considerably more resistant to destruction than any of the pathogenic organisms. Cl. botulinum A for example, mentioned in the text by Hoyt, Chaney and Cavell, is of no surgical significance, but in the canning industry it must be destroyed because, if allowed to grow in food products it leaves behind a toxic element of great potency. The important feature is that from the above data we now have clearly defined minimum limitations for surgical sterilization which permit the prescribing of standards which do carry ample margins of safety, with suitable and very necessary consideration for economic factors.

Chapter II

Analysis of the Functions of Steam in Sterilizing

It seems absurd after fifty years of extensive use of steam sterilizers in thousands of surgeries, that it should be found necessary to analyze the properties of steam as applied in sterilization but that is a very important detail which has been almost altogether neglected. This sort of information is needed by the surgical nurse as a background for sterilization. The vague theories which have been used for background are unsound, full of incorrect assumptions and inconsistencies, quickly revealed when the average sterilizer is subjected to analytical tests.

The Advantages of Saturated Steam as a Sterilizing Agency. It was discovered many years ago that microbes are destroyed by a process of coagulation of the bacterial protoplasm and studies were made with egg albumen, which is comparable, to determine the physical conditions which bring about coagulation. For coagulation at moderate temperatures, moisture is absolutely essential. The material saturated with water coagulates at (56 degrees C.–132 degrees F.)—much below the boiling point. But as moisture is abstracted, the temperature required for coagulation increases rapidly. Dehydrated egg albumen requires (170 degrees C.–338 degrees F.) for coagulation, temperature at which many surgical supplies would be burned up—destroyed.

This explains why saturated steam is preferable to dry hot air. The steam contains that essential factor—moisture, while dry hot air dissipates moisture—dehydrates the material. Hot air sterilizers are employed for some laboratory purposes such as the sterilization of glassware, and temperatures of 300 to 400 degrees F. are commonly maintained for one to two hours for complete sterilization.

Superheated Steam. Higher temperatures can be secured by passing saturated steam over heated surfaces or coils. By this process the steam is literally dried out and the peculiar advantages of a high moisture content, so necessary to sterilization, are dissipated. With every degree of superheat added to steam its sterilizing properties are reduced until temperatures are attained which destroy the bacteria by actual burning, as in the hot air sterilizer.

Steam Temperature Necessary for Reasonably Rapid Sterilization. Opposed to this, saturated steam at temperature of (115

degrees C.–240 degrees F.), to (121 degrees C.–250 degrees F.)—(10 to 15 lbs. pure steam pressure) will destroy the most resistant pathogenic spores in a brief interval of exposure. These temperatures are not destructive of surgical supplies, and the necessary period of exposure is well within practicable limits.

Why Pressure Steam is Used. Steam subjected to pressure is used rather than atmospheric steam for the sole purpose of attaining higher temperatures. Pressure of itself has nothing whatever to do with the destructive properties of steam. When water is boiled in an open vessel from which steam can escape freely, regardless of how much heat is applied, the temperature of the water or the escaping steam can never advance beyond the boiling temperature, (100 degrees C.–212 degrees F.) at sea level, or slightly under that temperature at higher altitudes. Steam at this lower temperature will destroy all pathogenic micro-organisms, the common vegetative forms or the spore types when in the growing or vegetative state, in a short period of exposure. It is known however, that spores of such dangerous forms as Cl. welchii for example, are much more resistant and will withstand prolonged periods of exposure to atmospheric steam. For this reason sterilization of surgical supplies is attempted only at the higher temperatures of pressure steam.

What is Meant by Fractional Sterilization: For certain laboratory purposes, it is desirable to sterilize media at temperatures not higher than that of atmospheric steam. For this purpose a special type of non-pressure sterilizer is employed (the Arnold sterilizer), in which the material is subjected to the steam from boiling water for one hour or more. Then the material is kept at incubation temperature over night, and again subjected on the second day, to another period of one hour or more sterilization. This is repeated on three successive days. The theory upon which this type of sterilization is carried out is that the first sterilization period destroys all vegetative forms of bacteria. Then during incubation over night some of the spores will develop into the vegetative stage and these will be destroyed by the second sterilization. The second period of incubation and the third sterilization usually result in complete sterilization. (It must be noted however, that for fractional sterilization, the material must be some form of media upon which bacteria can live, otherwise the spore forms will not develop into the vegetative stage.)

In some hospitals sterilization of surgical supplies is attempted by what is termed "fractional sterilization," by subjecting the materials to pressure steam sterilization on two or three successive occasions. This is not fractional sterilization at all because spores which might be present in surgical supplies have nothing to live upon and will not develop during the intervening periods into the vegetative stage.

This type of sterilization, while the intent to attain a high safety factor is commendable, is not practicable. Sterilization would be much more certain and there would be a distinct saving of time and steam by prolonging the first sterilizing period to known safe limits in a machine, the essential functions of which are properly gauged and controlled. It is noteworthy that such extreme precautions to safeguard sterilization as this so-called fractional method or the use of steam at abnormal and often highly destructive pressure for perhaps expensively long periods of time have been occasioned by the former lack of any means for measuring the bacteria destroying quality of steam in the sterilizer, its temperature.

How to Determine the Ultimate Temperature of Pure Steam or of Steam Mixed with Air at Any Pressure. Steam tables available in engineers' handbooks, show the temperature of pure saturated steam at various pressures. These steam tables can also be used to determine the ultimate temperature of any known mixture of steam and air at any gauge pressure. There is a radical difference, which fact is rarely appreciated by operators of sterilizers, and about this fact hinge most of the troubles encountered in sterilizing. To determine the ultimate temperature of a known mixture of steam and air, apply the following formula.

$$\mathrm{Pl} = \mathrm{Po} - \left(\frac{30\text{-v}}{2}\right) \text{(From Dalton's Law of gaseous pressures)}$$

In which Pl = absolute pressure, the temperature of which is the desired factor. (Determine this by reference to steam tables.)

In which Po = absolute pressure applied to the sterilizing chamber = gauge pressure plus 14.7 pounds.

In which V = the degree of vacuum applied to the sterilizing chamber in inches of mercury.

TEMPERATURE WITH VARIOUS DEGREES OF AIR DISCHARGE

Gauge Pressure Pounds	Pure Steam Comp. Air Discharge		⅔ Air Discharge (20″ Vacuum)		½ Air Discharge (15″ Vacuum)		⅓ Air Discharge (10″ Vacuum)		No Air Discharge	
	Deg. C	Deg. F	Deg. C	Deg. F	Deg. C	Deg. F	Deg. C	Deg. F	Deg. C	Deg. F
5	109	228	100	212	94	202	90	193	72	162
10	115	240	109	228	105	220	100	212	90	193
15	121	250	115	240	112	234	109	228	100	212
20	126	259	121	250	118	245	115	240	109	228
25	130	267	126	259	124	254	121	250	115	240
30	135	275	130	267	128	263	126	259	121	250

(Temperature Table Figure 2)

The operator of sterilizers need not make use of the above formula for other than a proper mathematical background for basic principles upon which sterilization depends. The actual temperatures attained in the sterilizer under ordinary conditions of proper and improper usage are given in the preceding table.

The Meaning of "Vacuum." The complete evacuation of air from a chamber defines a perfect vacuum. This is measured in terms of the height of a column of mercury which will be sustained under that

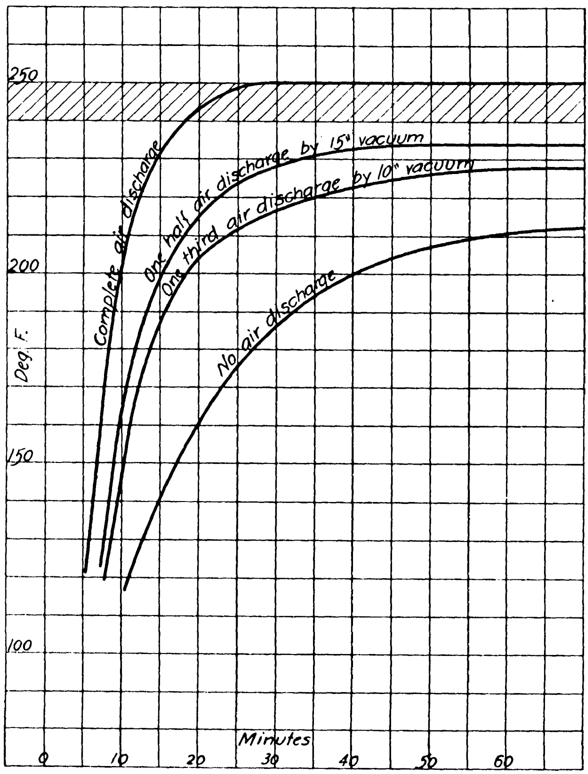


FIG. 3. When steam is admitted to a chamber from which air is completely evacuated, the temperature of the steam throughout the chamber will advance at once to the maximum range which can be attained for the pressure carried. If any part of the air remains in the chamber, the ultimate temperature will be reduced to a known degree dependent upon the quantity of air remaining, and as the percentage of air present is increased, the time required to attain even the reduced ultimate temperature will be increased.

These important facts, which bear directly upon sterilization, are illustrated by these four curves which were made by measuring the temperature in a 2000 cc. flask two-thirds filled with tap water under the conditions indicated. See also temperature table figure 2.

condition. This column of mercury is 30″ high. The combination vacuum-pressure gauges commonly used, are graduated for determination of the degree of vacuum to this scale, in inches of mercury.

The usual vacuum type sterilizer is equipped with an ejector valve by means of which a maximum of about 10″ vacuum can be secured. Occasionally a more powerful ejector is capable of creating 15″ vacuum, and in very rare cases 20″ vacuum can be produced.

There has been a great deal of misunderstanding relative to vacuum. Operators have been led to believe that "vacuum" plays some mysterious part in sterilizing—that it is difficult to sterilize except by first creating some relatively minor degree of vacuum. From the explanation given in the above paragraph it will be seen that 10″ vacuum means $^{10}/_{30}$ of a perfect vacuum, or in other words the exhaust of one-third of the air. 15″ vacuum exhausts one-half the air, and 20″ vacuum two-thirds. The temperatures resulting from such incomplete evacuation of air are not suitable for dependable sterilization as is indicated clearly by the temperature table, figure 2, and the temperature curves, figure 3.

How Gravity Affects the Mixture of Air With Steam in a Sterilizing Chamber. The relatively cool air in a sterilizing chamber is more than twice as heavy as steam at the normal sterilizing range. This means that when steam is forced by pressure into a sterilizing chamber containing air, the steam will literally float to the top of the chamber, compressing the air at the bottom. It is known, however, that the air and steam will ultimately mix, resulting in a uniform gas made up of steam and air, in which a part of the heat contained in the steam will have been absorbed by the air.

This mixing process which results after a long period of time in a uniform temperature throughout the chamber, is a most uncertain thing. Air and steam are reluctant to mix—do not mix until the air can gradually absorb part of the heat from the steam. The period required for this mixture to occur is affected materially by the character of the load and under no condition can it ever be determined precisely except by actual temperature measurements. However, the important details for consideration are:

(1) The presence of air greatly reduces the ultimate temperature of the steam below that of pure steam at the pressure carried. (See temperature table, figure 2.)

(2) Throughout the ordinary period of sterilization, the temperatures in the lower areas of the chamber will be materially lower than in the upper areas, due to differences in specific gravities and reluctance of steam and air to mix. (See temperature curves, figure 4.)

This latter fact accounts for radically misleading tests which are

often noted. A pledget of infected material placed in the upper part of a sterilizing chamber from which very little air has been evacuated, will frequently show complete sterilization because such materials will have been subjected, for at least a brief interval of time, to nearly pure steam at the pressure carried. Similarly sterilization

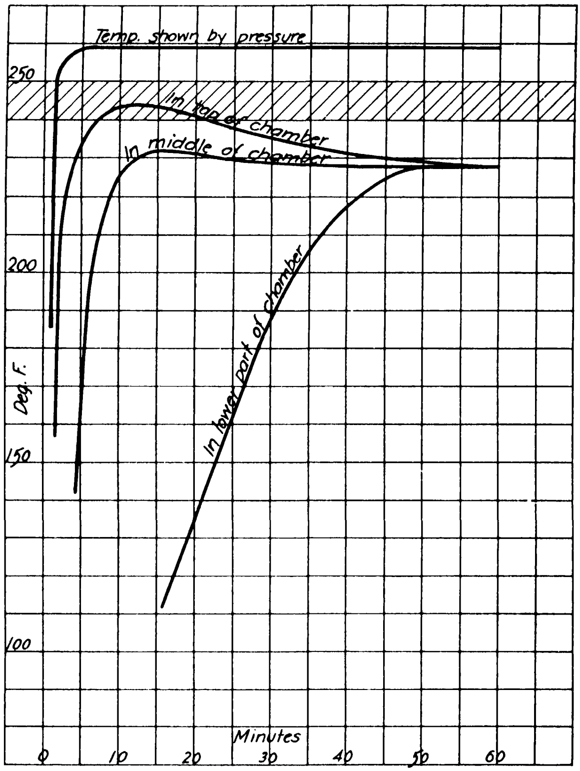


Fig. 4. Curves which show the radical differences in temperature which may be found in different parts of a sterilizing chamber from which air has not been evacuated.

One large package of loose muslin was used for this test in which three thermocouples were located, one close to the top, the second in the middle and the third close to the bottom of the chamber.

Air in such a chamber will gravitate promptly to the lower areas and the hot steam will float above until gradually but very slowly the air absorbs heat from the steam and mixes with the steam until the final uniform temperature has been attained.

This test is somewhat exaggerated since no air at all was permitted to escape. But the same relative condition applies always if some part of the air remains in the sterilizer. The cooler areas are always to be found at the extreme bottom, for which reason any test of sterilization should be made in the center of a package at the bottom of the load.

indicators such as Diack Controls located in the upper part of a poorly air-evacuated chamber, will often improperly indicate sterilizing conditions. Tests made in imperfectly evacuated chambers, at the bottom, will invariably show failure in any reasonable period of exposure.

To further illustrate the importance of this "gravity" feature, the reader's attention is called to temperature curves, figure 4. It is easily conceivable that tests made in the upper parts of this load might have indicated satisfactory conditions of sterilization, but it is certain that any test made in the lower areas must have failed.

The Condensation Process of Heating With Saturated Steam. An interesting property possessed alone by steam is its ability to heat materials, and particularly to permeate porous substances by the relatively rapid process of condensation, as opposed to the very slow process of heat absorption as would be the case if hot air or any other gas were used as the heating medium.

The condensation process of heating makes use of the latent heat of steam. In heating one pound of water from room temperature (70 degrees F.) and converting it into steam, at 212 degrees F., requires first the expenditure of (212 degrees − 70 degrees) = 142 heat units, to bring the temperature of the water to 212 degrees F. Then there must be added for each pound of water 970 heat units to convert that pound of water at 212 degrees F. into steam at 212 degrees F. This factor, (970 heat units), is known as latent heat. Then to heat this pound of steam at 212 degrees F. into steam at 250 degrees F. (15 lbs. pressure)—the normal sterilizing range, requires only 13.5 heat units. It is obvious that a very large percentage of the heat stored in steam, actually over 80%, is accounted for in the latent heat.

In abstracting heat from steam, for every pound that is condensed into water, surrounding objects absorb that latent heat. This factor is of tremendous importance in its application to the permeation, for example, of a package of gowns. As steam contacts the outer layer of fabric, the cooler substance immediately causes a film of steam to condense leaving in the fabric an infinitesimal quantity of water, that moisture so necessary in the destruction of bacteria and spores. The next film of steam does not condense in this outer layer because it has already been heated to the temperature of steam, but passes through and attacks the second layer of fabric—condenses and heats it. So on until the entire mass has been heated, after which the package will contain an amount of moisture (condensate) exactly equivalent to the amount of heat abstracted from the steam. Continuation of the process will cause no further condensation, but the temperature of the mass will remain constant at the temperature of the surrounding steam.

The Penetrating Power of Steam Is Seriously Retarded by the Presence of Air in the Sterilizing Chamber. The presence of air in the sterilizing chamber is a great handicap in sterilizing from many angles, first because it reduces the ultimate possible temperature of steam at any pressure; second, because of the reluctance of steam and air to mix, resulting in great variations in temperature in various parts of the chamber; third, because the ultimate reduced tempera-

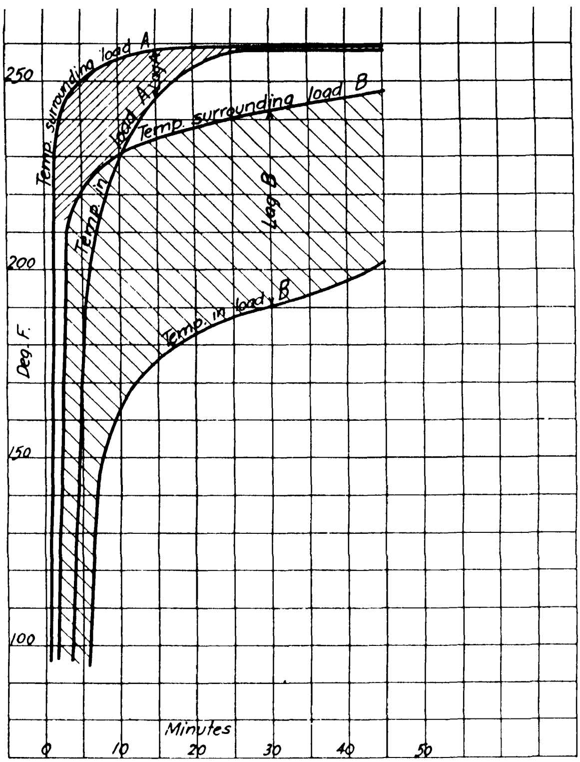


FIG. 5. Test to show the lag in steam penetration to be expected in a chamber from which air has not been evacuated.

A heavy package of Hampton pads was tested, first in a chamber from which air was completely exhausted, then the test was repeated in a chamber from which very little air was discharged. In both tests the pressure was carried at 20 lbs. and temperatures were taken just outside and in the center of the package.

It will be noted (lag A) that when the air was completely exhausted, the temperature in the package rapidly approached that of the surrounding steam. But when only a little air was discharged, the temperature in the package lagged approximately fifty degrees (lag B) behind that of the surrounding steam throughout a 45-minute exposure.

ture can be attained only after greatly prolonged periods of exposure. Finally because of its effect upon penetration which we shall now describe.

It has been explained how steam heats porous materials by its peculiar process of condensation. If air is mixed with the steam, obviously only the steam content of the mixture heats by the condensing process. The air content has no appreciable penetrating power. The heating or penetrating power of the mixture is reduced in this respect in accordance with the proportion of air present.

In addition, if the sterilizing chamber is well exhausted of air so that the free spaces all about the load are promptly filled with pure steam, then the air pockets within a bulky package of goods will dissipate rapidly by gravity (air is more than twice heavier than steam), to the bottom of the chamber from which an accurate gravity discharge system will permit its escape.

But if the chamber has not been evacuated of air, then there will be no material difference in density between the air pockets within the package and the air which has gravitated to the lower areas below the package. These pockets will therefore remain in the goods and greatly retard the entrance of steam.

The temperature curves figure 5, illustrate this very important matter convincingly, and further emphasize the need for placing any sterilization indicator in the heart of the package undergoing study rather than near the surface.

The Simple Gravity System Replaces the Less Accurate Vacuum System. From the foregoing paragraphs it is most obvious that the commonly used vacuum system, as a means for air elimination, falls far short of the requirement for accurate, dependable work. It is impossible with any known practicable apparatus to create vacuum of a sufficiently high degree to warrant its use at all. Particularly this is true in view of the fact that it is so very easy to evacuate a sterilizing chamber of air by the simple gravity process. (See figure 6).

Excellent Sterilization Can Be Accomplished by Skilful Manual Control of the Chamber Drain. We repeat that air at the usual sterilizing range is more than twice as heavy as steam, and that when steam is admitted to a chamber containing air, its physical tendency is to float above and to compress the air, at the bottom. We have only to open an exhaust valve at the bottom of the chamber to permit this air to escape. This can be done by hand manipulation of the chamber drainage valve and if the operator is skilful, absolutely ideal results will follow. The operator however must be very skilful and painstakingly careful in the matter of timing the period of exhaust and regulating the valve else this performance will result quite as ineffectually as the vacuum system.

How the Thermostatic Valve Permits Automatic Performance. There have been developed in recent years, thermostatic valves which can be used for automatic control of air and condensate discharge from such chambers with excellent results. These valves are of the general type commonly known as steam traps. They contain flexible metallic elements filled with volatile liquid which expands under heat or contracts when cool opening or closing the valve outlets.

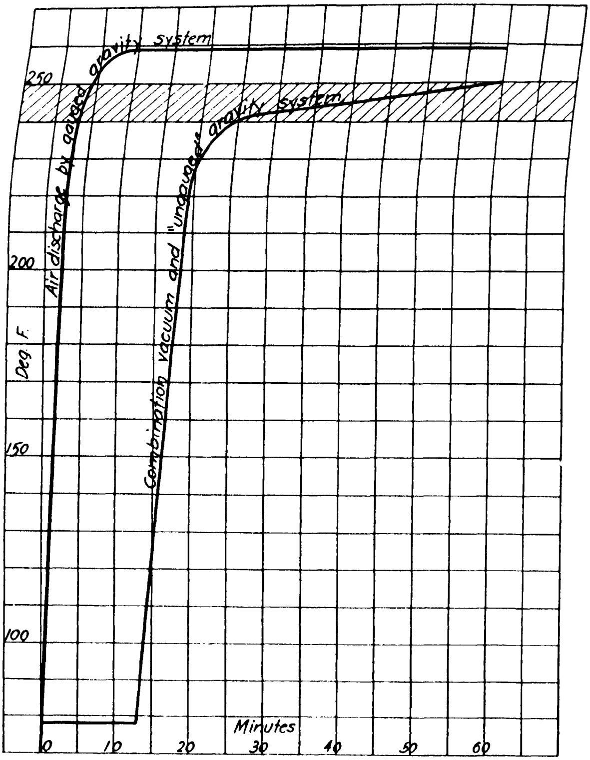


FIG. 6. A comparison between the (gauged gravity system) and the older (combination vacuum and ungauged gravity system) of air discharge.

This test was made with a very large sterilizer operated at 20 lbs. pressure for one hour periods. Temperatures were taken in the heart of a typically heavy package of surgical supplies, first with the sterilizer operated as it was being used daily with the vacuum system. Then the same package was tested in the machine after the gauged gravity system had been installed—with the remarkable results indicated.

The thermostatic control on the former vacuum system was not functioning but the unusually capable operators had no means for indicating this fact.

This test illustrates why, on former systems, it has been found necessary to increase pressures to abnormal ranges which often result in temperatures which are destructive of materials.

It must not be assumed, as too frequently is done, that the usual steam trap can be applied satisfactorily for this more delicate functioning. Many thermostatic steam traps are not adequate for satisfactory speed and thoroughness in discharging air. Usually such valves are so adjusted that they close off too quickly to permit the final discharge of air pockets which gradually gravitate from the load toward the discharge outlet.

But more sensitive thermostatic valves are available which have been specially designed for the purpose, which permit rapid and complete evacuation. *The proper application of such traps affords opportunity for the automatic discharge of all air from the sterilizing chamber, so that it is easy to attain very quickly—the maximum possible temperature throughout the chamber—the greatest sterilizing effect of the steam.* Fortunately these better grades of valves are fairly dependable—are not readily subject to structural changes in use which interfere with their functioning. The best of them, however, do fatigue after long service and it is always necessary to check their performance by some dependable means in every sterilization.

A Clogged Discharge Line Is a Dangerous Source of Failure. The story however is still unfinished. It is not difficult to prove that such thermostatic valves properly applied, will promptly evacuate the chamber of air. The difficulty lies in indicating to the operator that the discharge system has not become clogged with lint, shreds of cotton, sediment, perhaps altogether closed. This is an extremely common source of trouble. Under some not unusual condition the discharge outlet may become badly fouled during one sterilization.

Ordinarily the operator of such sterilizers has no means for detecting whether or not the drain line is clogged. Should the line be clogged, regardless of how expertly she may have operated the sterilizer otherwise, sterilization will be most indefinite in any reasonable period of time. The temperature resulting in the lower areas of the chamber might not even closely approach the sterilizing range. To illustrate this point, reference is made to the temperature table figure 2, and particularly to the temperature curves figure 3. In sterilizing solutions for example, a very easy load to heat normally, there may be a tremendous reduction in temperature and a corresponding increase in time required to attain even the reduced temperature if only a part of the air is discharged. Note particularly how ineffective the pressure reading may be in determining sterilizing influence. In every one of the tests shown on figure 3 the pressure was maintained uniformly at 15 lbs. Only when it is known that air discharge is complete or very nearly that, does the pressure gauge have any usable meaning whatever.

A Dependable Method for Gauging the Effectiveness of Air Discharge—A Direct Reading of the Quality of Steam in the Chamber. It is obvious that for precision work there must be some method for definite gauging of the degree of air discharge. That has now been made possible by the simple method of measuring the temperature

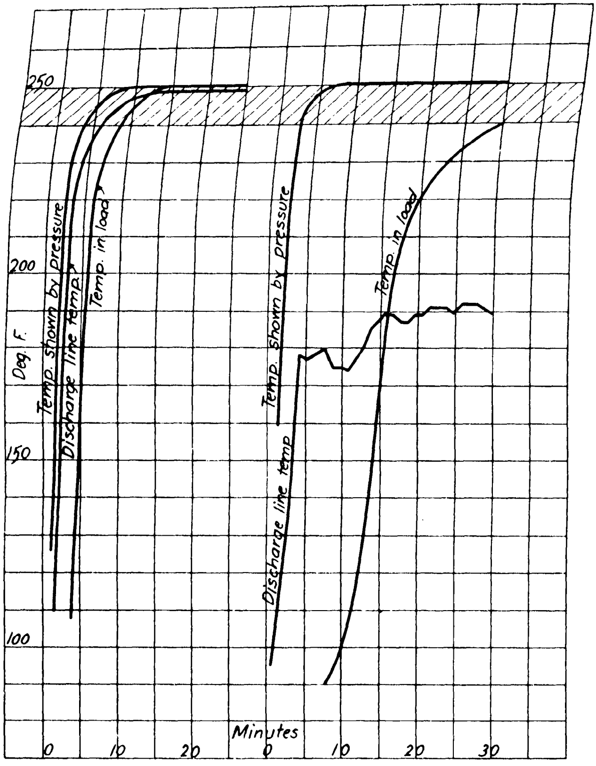


FIG. 7. These curves illustrate the purpose of measuring discharge line temperature. Temperatures were taken in the heart of a light package of muslin.

The curves at the left show results secured when the discharge line was clear and open as it should be. The discharge line temperature advanced rapidly to within two degrees of the temperature indicated by pressure. Correspondingly the load temperature advanced to the full value of the steam at the pressure carried—in 14 minutes.

The curves at the right were made with the same sterilizer and load, but the discharge line was clogged. The operator is warned of this condition by the discharge line temperature (gauge of performance)—which advanced slowly to 192 degrees only. Under this condition the load temperature came up only to 240 degrees after a 30-minute exposure.

Under the old (ungauged) thermostatic system, this clogged condition might occur at any time and the operator would not be aware of it. This sort of thing accounts for the old standard of conducting sterilization at excessive pressures—20 lbs. or greater, merely to cover the possible inaccuracies of the sterilizer.

in the discharge line. It has been shown that air or any mixture of steam and air, will gravitate to the lower areas of the chamber. It follows, an obvious physical fact, that if the discharge line is clogged there will be no material advance in temperature in the discharge line, but if the line is free, that the temperature will advance after the air has been driven out, and steam follows, to the temperature of the steam. Only when this has occurred will the indicated temperature advance to the sterilizing range. Even then this temperature will lag always a few degrees behind the *actual temperature of the medium with which the load is surrounded. The thermometer* reading will be, without exception, a measurement of absolutely the coldest medium within the sterilizing chamber. A partial clogging of the system will simply retard the movement of air, all of which will be indicated by the thermometer.

Gauge Sterilization Upon the Basis of Temperature Rather Than Pressure. With previous sterilizers it has been the common practice to measure the sterilizing period from the instant when the pressure gauge shows 15 lbs., perhaps 20 lbs., with very little regard for anything else. Often such measurements are made in a machine from which very little air has been exhausted.

Under the new system the period of sterilization is measured without immediate regard for pressure, instead from the instant when the thermometer in the discharge line shows temperature of 240 degrees F. (the equivalent of pure steam at 10 lbs.) and the minimum range considered safe for sterilization. This indication means always that the temperature of steam surrounding the load will range from one to five degrees higher in every part of the chamber. The lag will gradually reduce to one or two degrees as the sterilizing period advances and air pockets are gravitated from the load.

It is obvious of course that pressure must be regulated at the prescribed range in order that suitable temperatures can be attained and for every kind of heat nowadays it is a simple matter to provide for highly efficient automatic pressure regulation about which the operator of the sterilizer need not be greatly concerned. Her immediate and constant interest is centered in the maintenance of "discharge line temperature" which is indicative of these essential factors:

(1) that the air discharge system is or is not functioning properly.

(2) measurement of the temperature of positively the coldest medium surrounding the load—keeping that temperature within the prescribed safe range.

Simple Means for Keeping the Discharge System Free From Interruption. It has been shown that the almost invariable cause

for interruption to this system of sterilizing lies in the ever-present possibility that the discharge line may become clogged with sediment. A comparatively thin film of fine shreds of cotton over a screened surface will almost if not quite shut off the flow of air. Not the least valuable of the protective features on a safe sterilizer lies in the provision of facility for guarding against clogging at some inaccessible point such as the orifice of the thermostatic valve. A large, fine meshed screen on the inside of the sterilizer which can be *taken out by the nurse without tools and cleaned daily, is an essential item. If this screen is cleaned daily there will rarely be any interruption from this source. Should the thermometer fail to indicate the desired range when proper pressure is applied, that will indicate to the operator that the cleanout screen needs cleaning which can then be taken care of before proceeding. It may mean that the* thermostatic valve has frozen shut or is broken. In any event, failure to attain the prescribed temperature indicates a positive fault which must be corrected before attempting sterilization.

Now It Is Practicable to Reduce Pressure to a Range That Is Not Destructive. Due to the deficiencies of the average sterilizer with respect to the attainment of sterilizing temperature in a brief interval of time or perhaps at all, there has been a growing tendency for years to increase the pressure range and the periods of exposure beyond that actually needed. The pressure carried for surgical supplies in the average hospital is now approximately 20 lbs., in some instances considerably higher.

It is known that, for rubber gloves and glucose particularly, sterilizing at temperature higher than that of pure steam at 15 lbs. is destructive. It is also true that various fabrics show a distinctly destructive reaction to repeated sterilization at ranges higher than 15 lbs.

These higher pressures are no longer needed. They were never needed for sterilization but were carried only because there has been so much uncertainty about the attainment of temperature. For example, note the temperature curves in figure 8. These are the results of a test of a 2000 cc. flask of tap water. In the one test pressure was carried at 20 lbs. following a 10″ vacuum (withdrawal of just one-third of the air), with no further discharge of air—a quite common performance. In the second test pressure was carried at 15 lbs. following the "temperature measured" gravity discharge of air. The sterilizing influence at 15 lbs. in this case, is distinctly greater. These temperature curves are completely and properly illustrative of the differences to be found in comparing the older methods of air elimination with the system proposed. Of course a skilful operator of even a hand-controlled sterilizer would be able to duplicate the

results shown by this most efficient automatic machine. The point is that nurses are not always skilful and that precision performance demands some method of measuring—(gauging) the efficiency of the sterilizer in this respect.

Why Temperature of the Discharge Is Preferred to Internal Chamber Temperature. It might be asked why it is not desirable to measure temperature within the sterilizing chamber instead of in

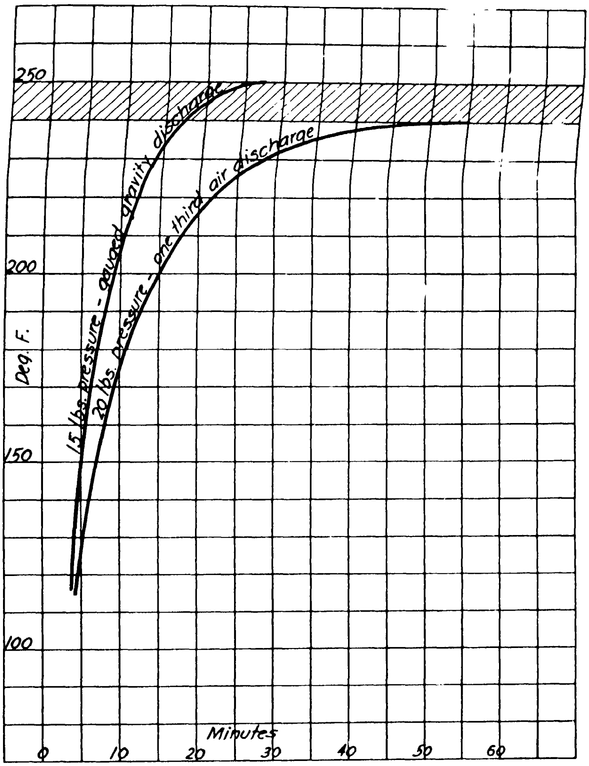


FIG. 8. Sterilization in an accurately controlled sterilizer, one in which the degree of air discharge is measured, may be distinctly more effective at 15 lbs. than at 20 lbs. in a machine from which air is discharged by some ungauged method.

Temperatures were taken in a 2000 cc. flask two-thirds filled with tap water. In the one test the pressure was carried at 15 lbs. and air was completely discharged through a thermostatic system containing a thermometer with which the operator could gauge the effectiveness of air discharge. The second test was made at 20 lbs. pressure in the same machine from which only one-third of the air was withdrawn by creation of 10″ vacuum before admitting steam. Similar performance is by no means uncommon. It might occur with any older type of sterilizer if the air discharge line became clogged.

the discharge system. The purpose is, to measure the effectiveness of air discharge which under all conditions is the fundamental requirement, and to indicate promptly if there is an interruption which must be cleared. A thermometer bulb placed at any fixed point within the sterilizing chamber would measure merely the temperature at that point—would reflect perhaps the temperature of circulating currents of steam—would not be so clearly indicative of the condition which the operator needs to know. In addition, the bulb of such a thermometer would necessarily be installed permanently at some point close to the steam jacket wall, out of the way of the load—giving free access to the chamber. In any such position, this thermometer bulb will reflect always to some extent the temperature of the hot steam jacket surrounding the chamber which is always filled with essentially pure steam.

We have shown in this chapter merely the engineering fundamentals of pressure steam sterilization—the factors which govern precise, dependable performance. There are other factors which are quite as important relating to the preparation of materials for sterilization and the actual loading of the sterilizer. Without due regard for these factors sterilization in the most perfect of sterilizers can easily remain uncertain.

Chapter III

Obsolete Type of Pressure Controlled Sterilizer, Air and Condensate Are Discharged From Chamber by Hand Control. No Thermometer is provided

Such sterilizers can easily be modernized to conform with the latest standards as illustrated in Chapter V.

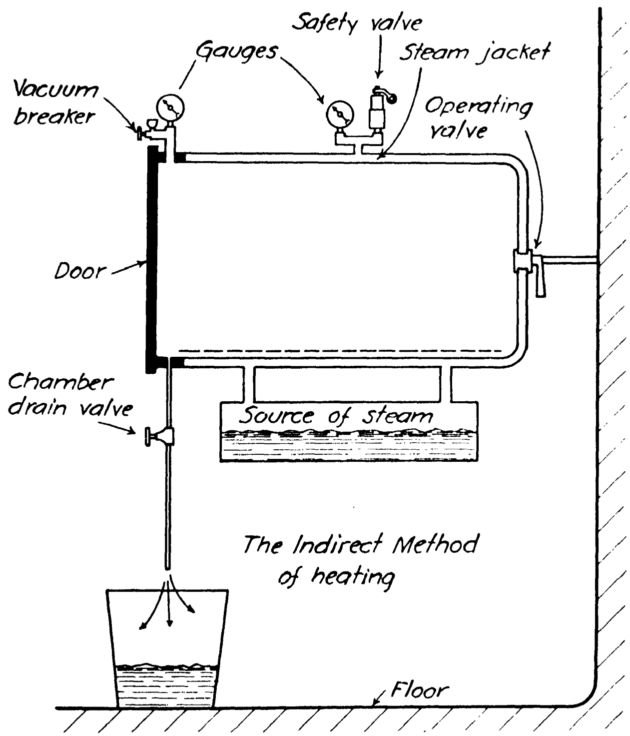


FIG. 9. Side view in section of a typical pressure steam sterilizer in which drainage of air and condensate from the sterilizing chamber is controlled by hand discharge into a vessel on the floor. This sterilizer is heated by the "indirect method." Steam for sterilization is generated by heat applied to the boiler suspended underneath the sterilizer.

The diagram Fig. 9 shows a side view in section of a typical pressure sterilizer in which drainage from the sterilizing chamber is controlled by hand regulation of the drain valve. Air, vapor and condensate are discharged from the sterilizer over a vessel on the floor in plain view of the operator. There are a great many sterilizers of this general style in every day use. With only slight modifications with reference to the type of operating valve used, and its location on the sterilizer, this machine was the generally accepted standard used for surgical sterilization until recent years.

Undoubtedly this type of sterilizer has distinct advantages over many of the modified so-called automatic types which followed, because while this type expressly demands more confining effort in operating, it offers the operator definite means for gauging the character of performance, lacking on many of the so-called automatic types, if she chooses to exercise skill and care in the manipulation of the drain valve. By watching the discharge from the drain outlet,

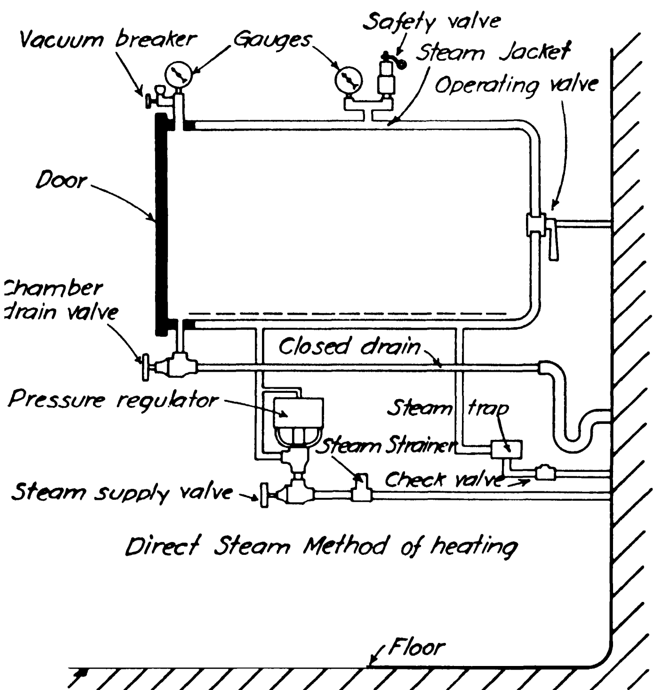


FIG. 10. This style of drainage connection is distinctly hazardous. Through the direct connection to the waste, sewage may be drawn back into the sterilizer under vacumn. This arrangement would pass no sanitary code.

the operator can be sure that there is no clogging effect, and she can time the period of air evacuation with precision.

Objections to the machine shown by Fig. 9 are offered because of the undesirable escape of vapor into the room from exhaust. Many of these sterilizers have been modified to exhaust the chamber discharge into a closed piping system as shown by Fig. 10. By this method of piping, the peculiar value of the original type is lost. The operator cannot detect whether or not the drainage system is clogged. She cannot be sure that any discharge occurs at all when the

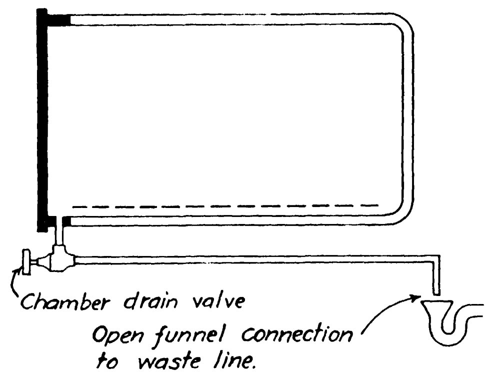


FIG. 11. The vessel on the floor for collecting condensate (Fig. 9) can be replaced by an open funnel connected to a trapped waste, as shown. This avoids the hazard of possible pollution by sewage.

drain valve is open. Otherwise this hook-up is dangerous because of the possibility by no means uncommon, of drawing back into the sterilizing chamber when under vacuum, of foul gases or waste products. By collecting the discharge in a vessel on the floor, or in a drained open funnel preferably close to the front of the sterilizer, these sources of difficulty are eliminated. Refer to Fig. 11.

At the period during which such sterilizers were produced, great emphasis was given in all operating instructions, to the importance, no longer conceded, of creating a partial degree of vacuum rarely in excess of 8 or 10 inches, for air evacuation prior to admission of steam to the sterilizing chamber. Very little attention was given to the far more important detail of regulating air discharge through the drainage system. This performance, as commonly prescribed and followed, was inefficient, particularly so when heavy loads of supplies were handled.

The average performance of a machine, so operated, could rarely result in uniform load temperatures in excess of about 240 degrees F., and this could be secured only after a considerably prolonged period of exposure. The initial 10″ vacuum could dispose of not more than one-third of the air, while the occasional brief and always indefinite opening of the drain valve to discharge condensate would

dispose of a slight additional amount of air—more or less accidentally. Complete sterilization under this method of control can occur if at all, only after prolonged exposure. At the best, such performances are always a bit hazardous and in the light of present knowledge of sterilizers and steam, should never be permitted in any surgery.

These old machines, assuming that they are otherwise in usable condition, can be made to operate efficiently, but only when operators are required to conduct the performance in strict accordance with the precise method of control later prescribed, which is quite at variance with the original method.

The method which we outline has been established by exhaustive study. It makes use of the gravity method of air discharge, the same method employed by the most accurate of modern sterilizers, except that the performance is hand controlled and timed. The temperatures attained are not measured.

Herein lies the hazard—that so much is dependent upon the human element. Inexperienced operators or those unfamiliar with the properties of steam, are prone to the invention of short cut methods, or to underestimate the importance of careful timing, which details if neglected, destroy the efficiency of the machine. The degree of safety in sterilizing with any hand controlled machine, is entirely in the hands of the operator. The results may be excellent or dangerous. The ultimate safeguard is the conscientious, well trained operator who understands the underlying principles, and who follows with unvarying detail the simple procedures outlined in the following paragraphs.

Method of Operating Pressure Steam Sterilizer—With Hand Regulated Control of Air and Condensate Discharge

(This safe performance requires practically constant attention of the operator)

1. **Turn on heat and secure jacket pressure of 15-17 pounds.** Place load in sterilizer, close and lock door. Open chamber drain valve one full turn.

2. **Turn operating valve to "sterilize"**—to admit steam to the chamber.

There should be an immediate discharge of cool air and vapor from the chamber drain valve (open 1 full turn), which should be followed by a gradually increasing voluminous flow of vapor and condensate. Watch carefully for this voluminous flow and do not check it by partially closing the valve until a full, measured five minute interval of time has elapsed.

When steam is admitted to the chamber during this process, it will

float to the top, compressing the much heavier air to the bottom, forcing it out through the open chamber drain valve. The flow of air, heavily charged with vapor and condensate, must be voluminous throughout the measured period of five minutes to properly evacuate the chamber of air. To reduce the flow or the period of time will surely interfere with sterilization.

During the 5 minute interval of air evacuation, the jacket pressure will usually reduce somewhat—may reduce to less than 5 pounds. The pressure will again be built up after the period of air evacuation.

During the period of air evacuation, the chamber pressure should never advance beyond 3 to 5 pounds. If it does advance beyond 5 pounds, that indicates that the chamber drain valve is not sufficiently open for adequate air discharge. The degree of opening should be regulated so that the chamber pressure does not advance beyond 5 pounds during air evacuation.

If a voluminous flow of vapor does not escape from the chamber drain during air evacuation, when the valve is properly open, that is evidence that the discharge piping is clogged. The sterilizer should not be used until this clogging effect has been removed.

3. **At the close of the 5 minute interval of air evacuation,** close chamber drain valve until only a light, feathery vapor mixed with drops of condensate escapes from the drain outlet. The drain valve should be nearly but never completely closed during the entire following period of exposure. Make sure of this condition by frequent inspections.

The chamber pressure (and the jacket pressure) should now gradually increase to the sterilizing range of 15–17 pounds. The slight discharge from the chamber drain valve will dissipate pockets of air which slowly gravitate from the load, and the condensate. If the valve is completely closed, sterilization will be less perfect, and the condensate will be re-absorbed and will cause wet dressings.

4. **Time the period of exposure when the chamber gauge shows 15 pounds pressure.** The heat must then be regulated, either by hand or automatically, so that chamber pressure is maintained constantly at 15–17 pounds throughout the entire period of exposure.

5. **The recommended periods of exposure** are based upon exact conformance with the above simple but extremely important details of control. The exposure periods have been reduced to the shortest, safe periods permissible under precise conditions. It is assumed that the loads have been prepared and placed in the sterilizer under the conditions outlined in Chapter IX. If any degree of laxity is permitted in the operation of the sterilizer, these recommended periods of exposure will not be adequate.

Pressure is to be maintained constantly at 15–17 pounds throughout these periods.

For dressings wrapped in double thickness muslin, or drums properly packed, 30 minutes.

Unwrapped instruments in trays, 10 minutes.

Instruments wrapped in muslin, 15 minutes.

Utensils wrapped in muslin, 15 minutes.

Rubber gloves in muslin packs, 15 minutes.

Flasks of solution never more than two-thirds filled:

1000 cc. flasks, 15 minutes.

2000 or 3000 cc. flasks, 20 minutes.

6. **At close of period of exposure for all materials except solutions.** (Do not turn off heat until goods are ready to remove from chamber.) Turn operating valve to exhaust chamber pressure, and open chamber drain valve 1 full turn. When chamber gauge shows zero pressure, close chamber drain valve tight and turn operating valve to "vacuum" position for 3 minutes. Then turn operating valve to "off" and open vacuum breaker valve.

As soon as chamber gauge shows zero pressure, unlock the door but do not open it, merely loosen it slightly—just enough to permit vapor to escape. Leave the door cracked in this manner for 5 minutes for light loads, or 10 minutes for heavy loads. Then open the door and remove the goods. The heat may now be turned off unless another load is to be sterilized at once. See Chapter VII for detailed explanations of drying methods.

7. **At close of period of exposure for all solutions.** Refer to Chapter XI for detailed explanation of this process.

Turn operating valve to "Off" and crack chamber drain valve very slightly, just enough to permit chamber pressure to reduce to zero in a period of not less than 7 minutes nor more than 10 minutes. Then only open door and remove flasks at once.

CHAPTER IV

Obsolete Type of Pressure Controlled Sterilizer in which Air and Condensate Are Discharged from Chamber Automatically—but without Temperature Measurement.

Such sterilizers, with only slight change, can be made to conform with the latest standards as illustrated in Chapter V.

In the preceding pages we have shown how air and condensate can be effectively discharged from the sterilizing chamber by hand regulation of the drainage valve. The obvious fault with that system is the necessity for complete reliance upon the individual, and the close attention required, the degree of safety secured being altogether a matter of the care and skill of the operator.

The aim of manufacturers of sterilizers for years has been directed toward some system which will automatically remove air and condensate from sterilizing chambers without reliance upon skilful manipulation of valves or any other precise and confining attention to the sterilizer.

To that end, on all modern sterilizers a thermostatic valve has been substituted for the hand controlled drain valve on older models. The thermostatic valve contains an expansion element which contracts when cool, opening the discharge orifice of the valve much the same as the former type is opened by hand. When this expansion element is heated, as when steam or a mixture of air and steam flows through it, following the initial cool air discharge from the sterilizer, it expands, tending to close the discharge orifice of the valve partly or altogether.

Such valves, designed and adjusted for air discharge, are available, and some of the better grades are remarkably accurate and dependable. Others of these thermostatic valves are the ordinary steam traps available from the nearest supply store, intended for an entirely different purpose than the control of a precision instrument in the discharge of air. The discharge orifice of the usual steam trap is so small that an abnormal period of time is required to evacuate a sterilizing chamber. Still more objectionable is the fact that some of these traps are designed to shut off—before air discharge is complete.

To illustrate more clearly how serious the faulty performance of a thermostatic valve may be, attention is drawn to a typical test case. Infections had occurred in a surgery which necessitated an investigation. First it was ascertained that the discharge system from the sterilizer was not clogged. The sterilizer was operated for one full hour at 20 pounds pressure, following an initial 10″ vacuum. In two tests the highest temperature secured in a moderately light load was 237 degrees F., 22 degrees less than that indicated by the pressure gauge. By substituting an accurate thermostatic air valve for the one found on the sterilizer, the temperature rose in the same load to 259 degrees in 18 minutes.

Dozens of such tests might be quoted where similar and equally important improvements have been made by the substitution of properly constructed thermostatic valves for ordinary steam traps. The important point is, that it must not be assumed that because the sterilizer is supposed to be automatic in this respect, that the discharge system is infallible, or that the valve will not fatigue after long service. No valve will remain permanently accurate. Every one is subject to change and requires constant checking to avoid the hazards of attempted sterilization with a chamber badly clogged with air.

Every discharge system, no matter how excellent the thermostatic valve may be, is subject to partial or complete clogging with lint, shreds of cotton, sticky masses of glucose or vaseline mixed with the sediment which drains from the sterilizing chamber. This clogging of valves and piping is the common and dangerous source of failure of any of the so-called automatic sterilizers. If the discharge system does become clogged, the automatic feature ceases to function, all efficiency is lost, and there is an unusual element of danger because the operators assume that the automatic feature relieves them of at least a large measure of responsibility.

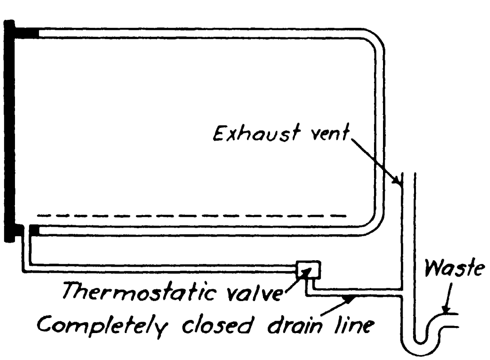
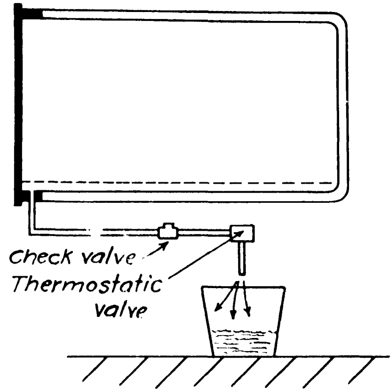


FIG. 12. A type of sterilizer in much too common use, having thermostatic control of chamber discharge, but no means whatever for checking performance—indicating a clogged condition. The discharge piping is carried to a closed vent and waste system with no intervening air break. With the chamber under vacuum as when drying a load of surgical supplies, a leaky check valve would permit intake to the sterilizing chamber of foul gases or waste products.

FIG. 13. A type of thermostatically controlled sterilizer in which the original hand operated drain valve has been replaced by a thermostatic valve. Operators object to discharge of steam into the room for which reason few of such sterilizers are in use. From a practical standpoint, it is a desirable method because the operator has unmistakable evidence that the valve is, or is not functioning as the case may be, just the same as with the hand controlled sterilizer. Nothing more contaminating than air from the room can be drawn into this type of sterilizer, when the chamber is under vacuum.



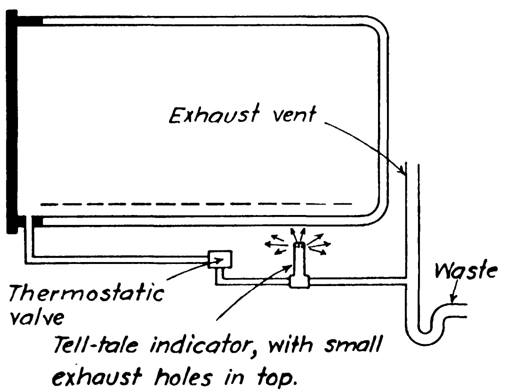
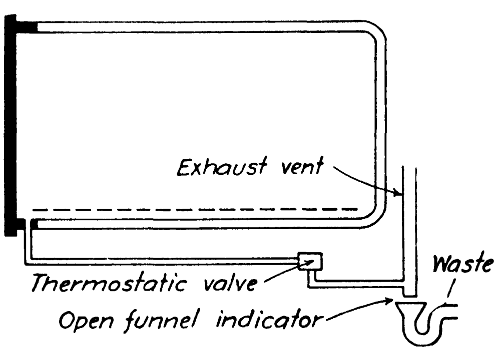


FIG. 14. A type of sterilizer with air break telltale indicator. When the thermostatic valve is discharging, there will be an indicative escape of steam from the small outlets in the indicator. This device is only partly indicative of the condition of the thermostatic discharge because the main flow of the discharge is concealed. Only a small portion is visible to the operator. There would be approximately the same escape of vapor if the line were half clogged, as with the line fully open.

FIG. 15. This type of air break tell-tale indicator provides an open funnel in the discharge system into which steam escapes when the thermostatic valve is discharging properly. The funnel is located usually so far from the front of the sterilizer that operators have difficulty in checking its action. Theoretically, it serves the purpose. It avoids the hazards of a completely closed system.



The diagrams Fig. 12–13–14–15–16, show the commonly used applications of thermostatic valves for the control of drainage systems. Not one provides any measurable check on the degree of air elimination. Every one of the tell-tale indicators illustrated will show more or less the same evidence of performance for a very inefficient thermostatic valve as for one which functions perfectly. The operator is helpless to determine which type she is using, except by constantly checking the results with some dependable type of sterilization indicator.

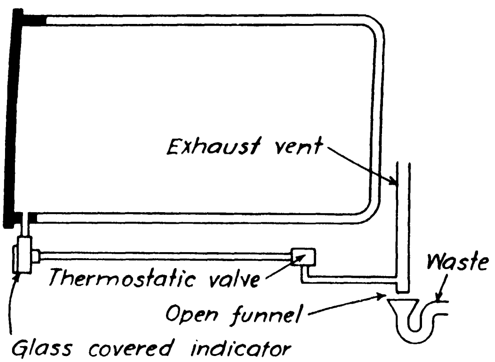


FIG. 16. This thermostatically controlled system has a glass covered, screened sediment pocket immediately under the door of the sterilizer through which all discharge from the chamber occurs visibly to the operator. This indicator provides the most definite evidence of, and the greatest protection against clogging of any of the so-called indicators or tell-tales.

All of the discharge from the chamber flows through this glass covered pocket which, when idle is always filled to half its depth with water. When steam is turned to the chamber, this pocket of water will be promptly discharged—if the thermostatic valve is working properly, and is not obstructed. Then during an interval of approximately 5 minutes, while the air is being dissipated from the chamber, the pocket will slowly fill again to half its depth. If the line is clogged at any point, there will be no discharge of water, affording positive evidence to the operator that the system is not working.

Like all others of these approximate indicators, this device does not detect a partial clogging effect, nor does it detect poor functioning of a thermostatic valve which may close off too soon.

The safe operation of any sterilizer of the general types illustrated by figures 12, 13, 14, 15, 16, in which there is no measured regard for the degree of air elimination and consequent internal temperatures, must provide for a large safety factor. With the original hand controlled air and condensate discharge system described by figure 9, the operator can by careful handling of the valves, duplicate a precise evacuation of the chamber from day to day securing the maximum temperature value of the steam. With any of these described, so-called automatic systems, if the thermostatic valve is faulty, the operator is helpless to detect partial interruptions to the air discharge system, and her only safeguard is higher than normal pressure and prolonged periods of exposure, and constant checks with

every load by some dependable type of sterilization indicator such as the Diack Control.

METHOD OF OPERATING PRESSURE STEAM STERILIZER—WITH THERMOSTATICALLY REGULATED CONTROL OF AIR AND CONDENSATE DISCHARGE, USING VARIOUS TYPES OF TELL-TALE INDICATORS OF AIR DISCHARGE, BUT WITHOUT MEASUREMENT OF TEMPERATURE

Refer to Cuts 13–14–15–16

Some sterilizers are equipped with removable screens at the point of outlet from the sterilizing chamber to the discharge system. If such a screen is provided, it should be removed from the sterilizer and thoroughly cleaned daily.

1. **Turn on heat and secure jacket pressure of 18-20 pounds.** Place load in sterilizer. Close and lock door.

2. **Turn operating valve to "vacuum" position** and secure 10″ vacuum as indicated by chamber gauge.

It is considered desirable to use the vacuum system with this type of sterilizer for the preliminary partial evacuation of air from the chamber, because of the frequently uncertain condition of the thermostatic valve. If the discharge line is partly clogged, or if the valve is the type which closes off too soon, the 10″ initial vacuum will dispose of at least one-third of the air.

3. **As soon as chamber gauge shows 10″ vacuum,** turn operating valve to "sterilize"—to admit steam to the chamber.

Now it is essential for the operator to watch the discharge line indicator, of whatever type it may be, to detect any signs of clogging.

With types figure 13–14–15, there should be an immediate and easily perceptible escape of vapor into the room, and this flow of vapor should continue for about 5 minutes or more. Thereafter, during the remainder of the period of exposure, there should be some slight leakage of vapor, perhaps at intermittent periods. If no vapor escapes at all from the indicator, or if the escape is feeble, or if the escape continues voluminously only for one or two minutes, call a mechanic at once before the sterilizer is used, to clear out the clogging effect, which may be found in the check valve or in the thermostatic valve.

With the glass covered indicator, figure 16, there should be a pocket of water half the depth of the glass cover, clearly visible when the sterilizer is idle, or when the chamber is under vacuum just prior to the admission of steam to the chamber. When steam is turned to the chamber, this pocket of water should be blown out promptly

within half a minute, and drops of water should be seen flowing over the inside surface of the glass. Then, gradually, through a period of about 5 minutes the pocket should again fill to about half its depth with water, if the sterilizer is functioning properly. If the pocket of water is not discharged promptly and completely as described, a mechanic should be called before the sterilizer is used to check the source of interference. This indicator has a large screen in the back of the sediment pocket which should be cleaned first. If the screen is clear, the interruption may be found in the check valve in the rear of the sediment pocket, or in the thermostatic valve.

4. **Time the Period of Exposure When the Chamber Gauge Shows 15 Pounds Pressure.** The heat must then be regulated either by hand or automatically so the chamber pressure is maintained constantly at 18–20 pounds throughout the period of exposure, except for rubber gloves. If the heat is hand regulated, this will necessitate almost constant attention of the operator.

5. **Recommended Periods of Exposure.** These are based upon the need for an abnormally high safety factor to cover the possible but indeterminate faulty performance of the thermostatic valve in properly evacuating the chamber. These recommended periods of exposure follow very closely those which have been established in carefully supervised surgeries where tests have been made over long periods of time to determine safe ranges.

Many of these sterilizers at times will perform with excellent efficiency. Under this condition, sterilization will occur perhaps in half the time prescribed, or less. The prolonged periods of exposure and the higher than normal pressures recommended serve as a safeguard against those occasions when the thermostatic air discharge system becomes ineffective.

For dressings wrapped in double thickness muslin, or drums properly packed, 45 to 60 minutes at 18–20 pounds pressure, for light or heavy loads. See preparation details chapter IX.

Unwrapped instruments in trays, 15 minutes at 18–20 pounds pressure.

Instruments wrapped in muslin, 20 minutes at 18–20 pounds pressure.

Utensils wrapped in muslin, 20 minutes at 18–20 pounds pressure.

Rubber gloves in muslin packs, 20 minutes at 15–17 pounds pressure.

Flasks of solution never more than two-thirds filled: 1000 cc. flasks, 20 minutes at 18–20 pounds pressure. 2000 or 3000 cc. flasks, 25 minutes at 18–20 pounds pressure.

6. **At Close of Period of Exposure for All Materials Except Solutions.** (Do not turn off heat until goods are ready to remove from

chamber.) Turn operating valve to exhaust chamber pressure. When chamber gauge shows zero pressure, turn operating valve to "vacuum" position for 3 minutes, then turn operating valve to "off" and open vacuum breaker valve. (Some sterilizers automatically control breaking of vacuum when the operating valve is turned to "off.") As soon as the chamber gauge shows zero pressure, unlock the door but do not open it, merely loosen it slightly—just enough to permit vapor to escape. Leave the door cracked in this manner for 5 minutes for light loads, or 10 minutes for heavy loads. Then open the door and remove the goods. The heat may now be turned off unless another load is to be sterilized at once. See chapter VII for detailed explanations of drying methods.

7. **At Close of Period of Exposure for All Solutions.** Refer to chapter XI for detailed explanation of this process.

Regulate operating valve most carefully toward the exhaust position so that chamber pressure will reduce to zero in a period of not less than 7 minutes nor more than 10 minutes. Then only open the door and remove flasks at once.

Chapter V

The Modern Temperature Controlled Sterilizer

Older types of sterilizers described in chapters III and IV can usually be modernized to conform with this system illustrated in Fig. 17.

At some length we have explained the hazards to be encountered in any of the commonly used methods of gauging sterilization on the basis of pressure with indefinite knowledge of the degree of air elimination, which factor determines the degree of temperature attained.

Any one of the previously described thermostatically controlled sterilizers might perform with a close approach to one hundred per cent efficiency, but not one of these machines is equipped with any device by means of which the operator can prove to herself or to an observer that she has secured adequate sterilizing temperatures. She knows only that pressure has been maintained for a measured period of time, and presumably she has taken certain precautions, none of them definite or measurable, to secure air elimination to obtain pure steam. She has not measured the sterilizing effect of the steam and can produce evidence that she has sterilized only by the constant use of dependable sterilization detectors, such as Diack Controls.

This fault is being emphasized with a particular purpose in view. It is rather absurd that a detail as important as sterilization for surgery should be conducted without precise knowledge of the sterilizing effect applied. It is almost as absurd that to cover up uncertainties, there should be resort to expensive safety factors such as abnormally high pressure, and abnormally prolonged periods of exposure—to safeguard the operation of a sterilizer with no attempt being made to gauge the true sterilizing influence of the steam.

That detail is, or should be, the fundamental aim in sterilizing—to measure the actual bacteria and spore destroying property of the steam contained in the chamber. By such a system only, is it possible to eliminate the common hazards which otherwise every surgery daily contemplates—the possible use of supplies which have been subjected to known pressure, but absolutely unknown temperature—goods which may be unsterile.

It is recommended that the reader again refer to the temperature curves resulting from pressure applied with varying degrees of air elimination shown by figure 3. Read the accompanying text again and gain a clear knowledge of how adversely sterilization is affected

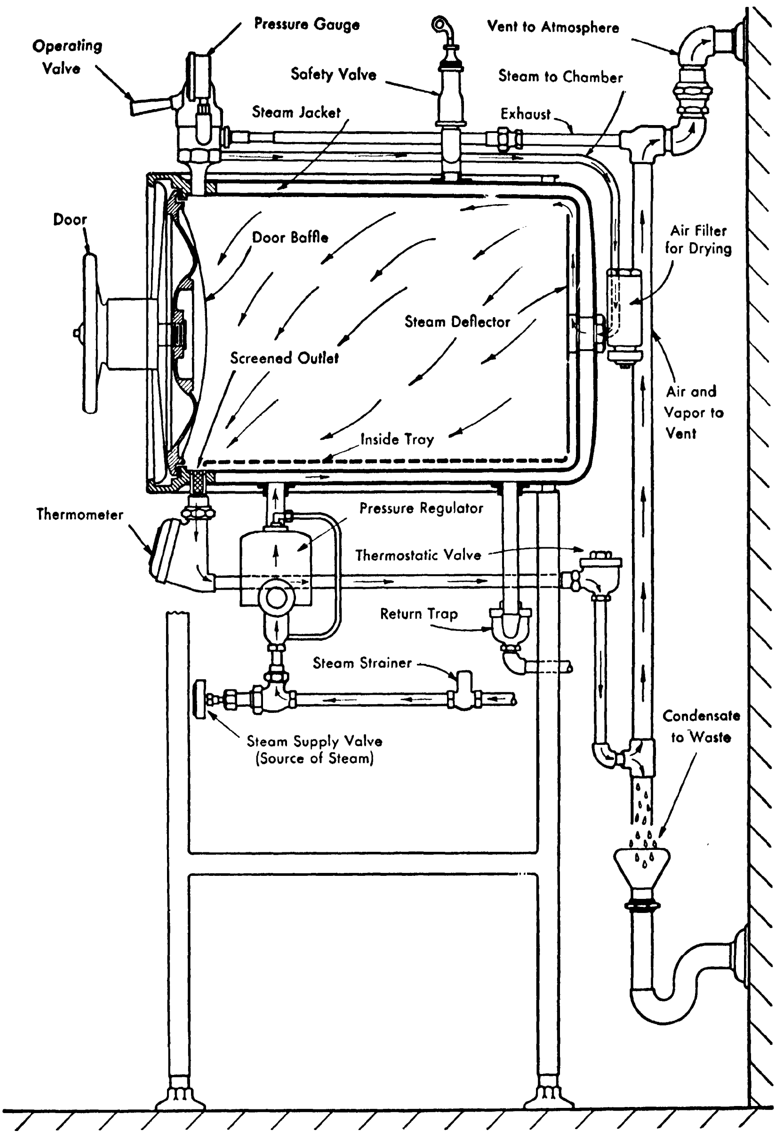


FIG. 17. Longitudinal section of modern sterilizer. Steam is delivered from the source to the steam jacket, through a pressure regulator which automatically maintains the desired range. The same principle applies for steam heat (as indicated) or for gas or electrically heated sterilizers.

by incomplete air elimination. Refer also to the curves in figure 4 which show the varying temperature conditions which may occur in different parts of the sterilizing chamber, under inadequate conditions of air elimination.

By examination of these curves, it will be quite evident that we have not over stressed the importance of measuring the degree of air elimination by the temperature method. It will be plain also that measurement of the temperature within the sterilizer at any fixed point will denote merely the temperature at that point. What the operator needs to know is -not any of these interior temperatures which may vary, but the lowest temperature of the applied sterilizing medium.

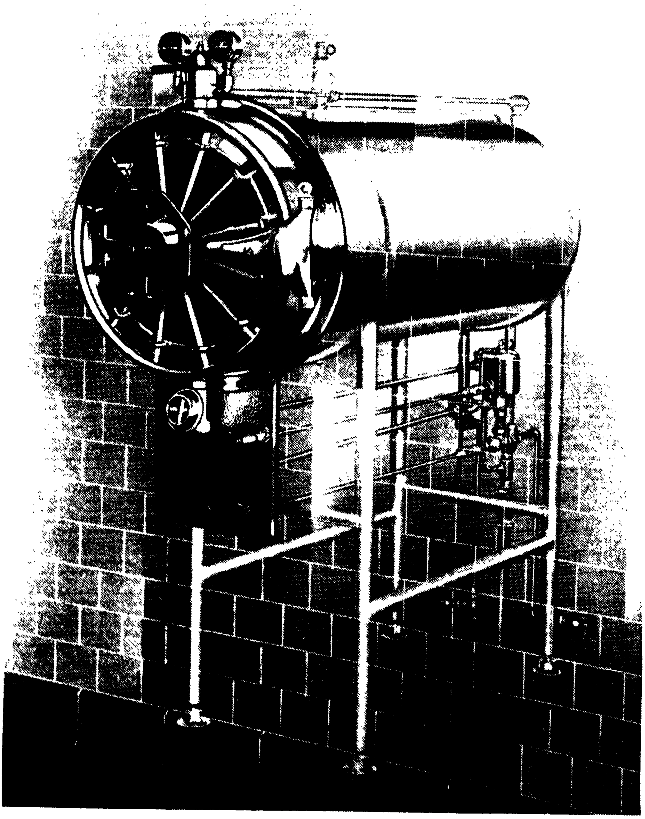


FIG. 18. Temperature controlled Pressure Steam Sterilizer Steam heated. Showing how the sterilizer is built-in or concealed.

That temperature will be found always in the discharge outlet of the sterilizing chamber. Air contained in the chamber is more than twice heavier than pure steam. Any mixture of air with steam will be heavier than pure steam. The result is obvious but interesting. The coolest part of the sterilizing medium will gravitate unfailingly to the bottom of the chamber and to the discharge outlet. If the temperature of the discharge is measured just as it leaves the chamber, there will be a direct measurement of the bacteria and spore destroying effect of the steam.

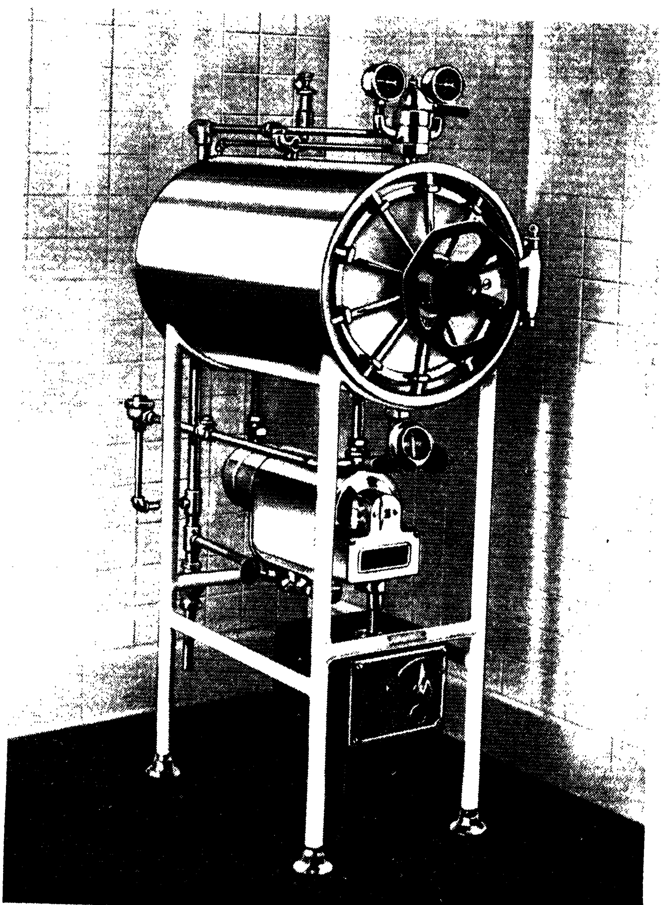


FIG. 19. Temperature Controlled Pressure Steam Sterilizer Electrically heated.

With this sytem we are no longer interested in pressure except as a contributing factor. Sterilization still occurs under pressure, but the sterilizing effect of the steam and the period of exposure are based upon the attainment of adequate sterilizing temperature in the coolest part of the chamber. Perfectly safe limits of temperature, but not excessive and injurious degrees of temperature; and ample but not abnormally prolonged and expensive periods of exposure are prescribed.

If air is properly evacuated from the chamber of the sterilizer Fig. 17, the temperature will advance to the minimum prescribed sterilizing range (240 degrees F.) in 2 to 5 minutes. This temperature will then continue to advance for another 2 to 5 minute interval, depending upon the size of the sterilizer and the character of the load until a maximum has been reached, which will always lag behind that indicated by the pressure, by 2 or 3 degrees, due to the cooling effect of the condensate which drains from the chamber constantly.

If the air and condensate discharge system is completely closed, either by clogging or by faulty performance of the thermostatic valve, the temperature will never rise, even closely to the sterilizing range, thus affording definite indication of serious trouble, which should of course, be corrected before the sterilizer is used.

If the discharge system becomes partly clogged, or if the thermostatic valve fatigues and becomes sluggish, the temperature will rise to the prescribed range only after a prolonged period of time. It will never rise to this range unless the far greater portion of the air has been discharged. The sluggish building up of temperature indicates to the operator that there is some interference which needs correction.

The sterilizer can also be equipped with a recording thermometer containing a clock mechanism which revolves its chart once in 24 hours. An ink pen records on the chart the temperatures attained, and the exact period of exposure for each sterilization performed during the day. It is desirable to use both the indicating type mercury thermometer, and the recorder thermometer because the mercury type thermometer will remain, except by breakage, permanently accurate within one degree at the sterilizing range. Recorder thermometers, even the most expensive types, are subject to some change or distortion of the pen-arms. Such changes, if they do occur, can easily be checked and corrected, by comparison with the mercury instrument.

The recording thermometer is emphatically recommended for every surgical sterilizer. It aids materially in standardizing precise methods of sterilizing, avoids errors in timing periods of exposure, and it furnishes a record day by day of every sterilization for the in-

spection of the supervisor, or the surgeon who may wish to investigate the methods followed. It also furnishes a permanent file record of the work done. If operators grow careless in handling the sterilizer, that fact will immediately show up on the chart record. An excellent procedure in the maintenance of very high standards is to require the supervisor or some other responsible person to check the chart record for each sterilization, at the close of the period of exposure before the goods are removed from the chamber. Inaccuracies or any departures from prescribed methods may be caught in this manner, and the load resterilized if need be.

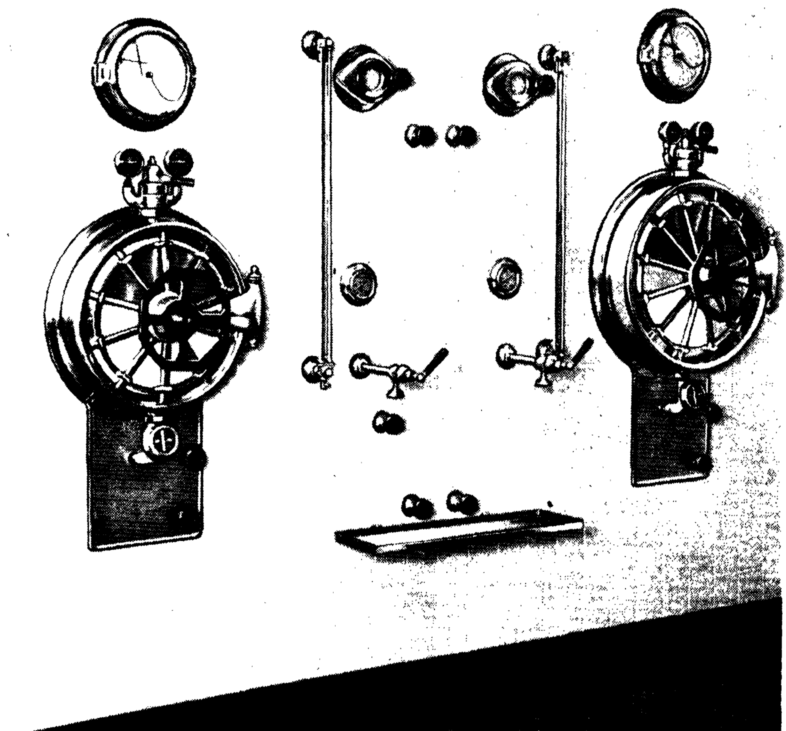


FIG. 20. Battery of built-in sterilizers each with recording thermometer, with a pair of water sterilizers mounted between. All units steam heated.

Method of Operating Pressure Steam Sterilizers with Temperature Gauging of Thermostatic Air and Condensate Discharge

Before applying this method of sterilizing, read carefully the methods of loading recommended in chapter IX.

1. **Clean out the strainer** on the inside of the sterilizer at the entrance to the discharge outlet. Remove all lint, shreds of cotton and sediment until the pores of the screen are open.

2. **Turn on heat and secure jacket pressure of 15-17 pounds.** Place load in sterilizer, close and lock door.

3. **With jacket pressure 15-17 pounds, turn operating valve to "sterilize"**—admit steam to the sterilizing chamber.

If the discharge system is unrestricted, the temperature shown by the indicating thermometer (and the recording thermometer, if one is used) should advance gradually to 250–254 degrees F. Timing of the period of exposure can safely be made as soon as this temperature has advanced to 240 degrees F. The interval of time needed to build up to this temperature should be about 2–4 minutes. This temperature will never be attained unless the discharge system is sufficiently free for the evacuation of essentially all air.

If the temperature does not advance to 240 degrees within a period of 2–4 minutes, the sluggish action may be due to a partial clogging of the screen in the entrance to the discharge outlet in the bottom of the sterilizer. If this screen is clear, then there will usually be found a sticky mass of sediment mixed with glucose or vaseline, which has accumulated in the thermostatic valve, which should, of course, be cleaned out. This sort of stoppage should occur only at long intervals. The sluggish action may be due to a fatigued condition of the thermostatic valve, in which case the valve element should be renewed, or a new valve substituted.

If the temperature does not advance to 240 degrees at all, that is definite indication of a badly clogged discharge line, or the fault may be found in a defective thermostatic valve. Under no condition should attempt be made to use the sterilizer at all, unless the discharge line temperature has advanced to 240 degrees before timing the period of exposure.

At weekly intervals, remove plug screen from bottom of sterilizer at entrance to chamber discharge system, and pour in one pint or more of boiling hot tri-sodium-phosphate solution (strong) as fast as it will flow through. It will cleanse the interior of the system from grease and other sticky substances which tend to clog the line.

If the discharge line temperature advances barely to 240 degrees F. when the pressure is maintained at 15–17 pounds, check first the

accuracy of the chamber pressure gauge. If this seems to be correct, the interruption will probably be due to a faulty thermostatic valve —one of those which closes off too soon. It should be promptly replaced. Temperatures should advance in 4 to 8 minutes to a maximum of 250–254 degrees F.

4. **Time the Period of Exposure When the Thermometer Indicates 240 Degrees F.** Check this point with the mercury thermometer, then the recording thermometer, if one is provided. Care should be taken to regulate the heat control so that the jacket pres-

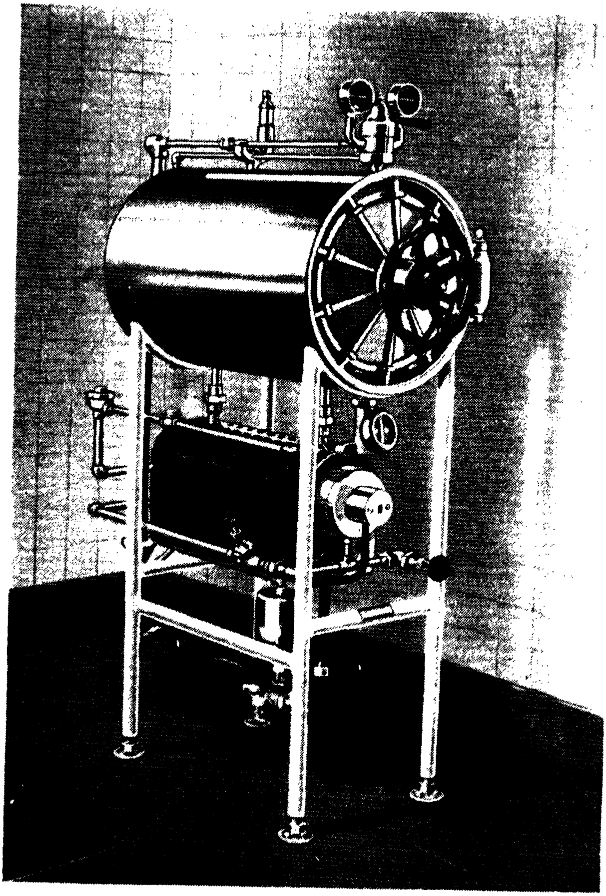


FIG. 21. Temperature controlled pressure steam sterilizer. Gas heated.

sure is dependably maintained at 15–17 pounds throughout the sterilizing period.

5. **The Recommended Periods of Exposure.** Attention is called to the fact that we are no longer in doubt about the quality of the steam applied. It is no longer necessary to apply abnormally high pressure or abnormally prolonged periods of exposure to overcome the possible inefficiency of the machine.

Periods of exposure recommended are based upon preparation of goods and loading in accord with the text in chapter IX.

Dressings in normal size packs in double muslin covers	30 minutes.
Moderately loaded drums with double muslin liners	30 minutes.
Fully loaded drums with double muslin liners	45 minutes.
Utensils, nested, in double muslin covers	15 minutes.
Utensils, single, in double muslin covers	10 minutes.
Instruments in trays with or without muslin covers	10 minutes.
Instruments wrapped for storage	15 minutes.
Rubber gloves in double muslin wrappers, not stacked	15 minutes.
Transfusion or intravenous sets or catheter trays	15 minutes.
Solutions (2000–3000 cc flasks) (thin glass)	20 minutes.
Solutions (1000-1500 cc flasks) (thin glass)	15 minutes.
Solutions (500 cc flasks (thin glass)	12 minutes.
Solutions (125–250 cc flasks) (thin glass)	8 minutes.
Solutions (50 cc flasks) (thin glass)	6 minutes.

Exhausting Steam From Chamber For All Materials Except Solutions; See Chapter VII. At close of exposure period, turn operating valve to Exhaust until the chamber gauge shows zero pressure. Then turn the operating valve to Dry for a period of 5 to 10 minutes, depending upon size and density of load. Then turn operating valve to the Off position and open the door.

In this modern machine, drying is accomplished by an ejector valve which pumps clean air through an air filter to the chamber and through the chamber to an exhaust outlet leading to a vent. The circulating air serves as a vehicle to conduct vapor from the load as rapidly as it forms. During this period the chamber gauge should show only a slight degree of vacuum, of no particular significance since drying is accomplished by the residual heat in the load and the heat from the hot jacket. Rapid evacuation of vapor prevents reabsorption and leaves the chamber relatively free from steam which otherwise escapes into the room when the door is opened. If appreciable vapor does escape when door is opened, that indicates need for a longer period of drying.

To Cool Solutions Following Sterilization. See Chapter XI. At close of period of exposure, turn operating valve slightly toward the exhaust position, regulating the valve most carefully so that chamber gauge shows a very slow loss of pressure. The period during

which chamber pressure reduces to zero should not be less than 7 minutes nor more than 10 minutes. This regulation of the valve requires some practice but the point of slow exhaust must not be ignored or the flasks will boil vigorously loosing part of the fluid. Slow loss of pressure is usually accomplished with the valve dial set at about ¼″ away from the index for exhaust. Remove solutions at once when door is opened.

Chapter VI

Bulk Type Pressure Steam Sterilizers

(Sometimes referred to erroneously as disinfectors.)

These are used extensively for sterilization of mattresses and bedding and in large hospitals for bulk sterilization of surgical supplies and in industry for commercial sterilization of various products.

These large steel constructed machines, sometimes cylindrical in shape—more often rectangular, have been commonly used for many years for the sterilization of mattresses and bedding. More recently they have been extensively used for sterilization of surgical supplies in large hospitals.

Older types of bulk sterilizers were usually piped to carry the full steam line pressure in the steam jackets, pressure ranging from 40 to 60 pounds or higher. With such arrangements of piping, a reducing valve was supplied, by means of which the high jacket pressure could be reduced automatically to the common sterilizing range of 15–20 pounds for the sterilizing chamber.

It was formerly thought that the high jacket pressure was of special value in the drying of goods. Later it was found that the increased pressure serves no useful purpose whatever, is on the contrary, harmful because it develops a significant degree of superheat, highly injurious to many fabrics. Superheating of steam distinctly detracts from its sterilizing properties because it dries out the steam —reduces its moisture content. Internal temperatures are frequently detected in such machines, ranging as high as 280 to 300 degrees F., while the chamber pressure is only 15–20 pounds, which should develop temperature not to exceed 250–259 degrees. For this reason, very largely, bulk type sterilizers have sometimes been criticized because of the destructive effect on mattresses and surgical supplies.

This older system of piping, due in part to the carrying of higher pressure in the jacket than in the chamber, was quite complicated, so much so that errors in performance were experienced. The system of air elimination was a combination of vacuum combined with hand control for the chamber drain. The internal temperature results were rarely satisfactory and never definite.

Connected as indicated, by figure 22, these machines can be used for mattress and bedding sterilization, or for surgical supplies without danger of destruction of the supplies from excessive temperature. The sterilizing temperature is controlled within perfectly adequate and known lower limits, and no superheat is developed by the jacket.

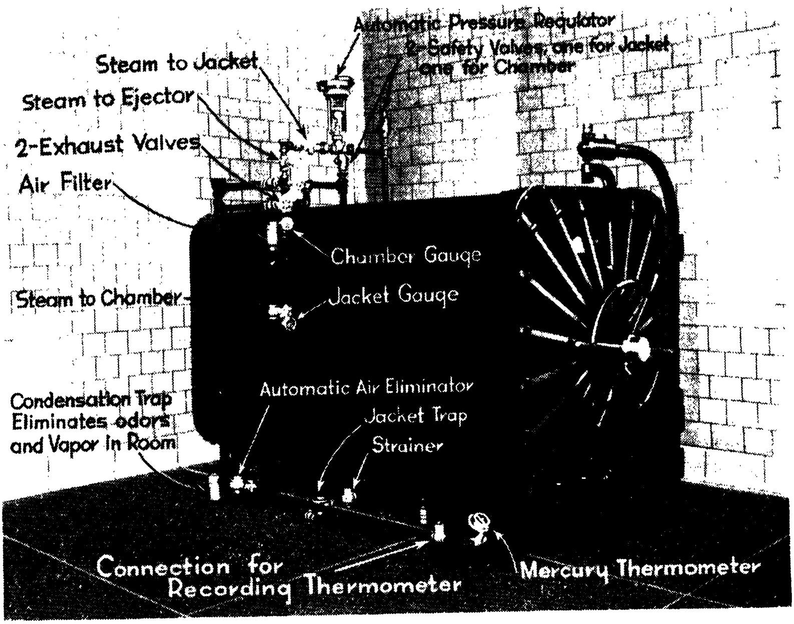


FIG. 22. Typical Bulk-Sterilizer Showing Piping and Valves.

Where the requirements are very great, these machines are undoubtedly far more economical because enormous loads can be sterilized in one operation. Some of the larger hospitals regularly sterilize loads of two or three hundred pounds, with no difficulty.

The proper loading of mattresses in these machines is important. They should never be rolled up in the sterilizer, but should lie either flat side down, or on edge. If the sterilizer is large enough to accommodate a mattress flat side down, it is usually equipped with several removable perforated shelves. Place only one mattress on each shelf—never one on top of another in close contact. It is perfectly satisfactory to place several mattresses on edge in the carriage, side by side. Sufficient steam space will be provided between the mattresses for thorough permeation.

Proper arrangement of a load of surgical supplies presents some problems which are not difficult to overcome. If the sterilizer carriage contains several flat shelves, these afford ideal loading facilities. The shelves are usually spaced 12 to 15 inches apart, which prevents the stacking up of dense masses without intervening steam circulation space.

If the carriage is of the basket type, without shelving, the load may

be placed in drums which must always lie on edge in order to eliminate air from the drums, or heavy galvanized wire baskets can be secured, 12 to 15 inches wide, 12 inches deep and 24 inches long, approximately. These wire baskets facilitate the handling of heavy loads of muslin covered packs into and from the sterilizer, and they can be stacked economically within the chamber without danger of eliminating steam circulation spaces in the load.

Elimination of Odors and Vapor from the Room. Not the least of the advantages of the modern sterilizer, especially when used for mattress sterilization, is the elimination of odors and vapor from the room. In drying the load, an ejector valve provides, in effect, a pumping action which draws steam and odors from the chamber and discharges them to a vent. Filtered air is drawn into the chamber during the evacuation process which permits practically complete aeration of the load to occur.

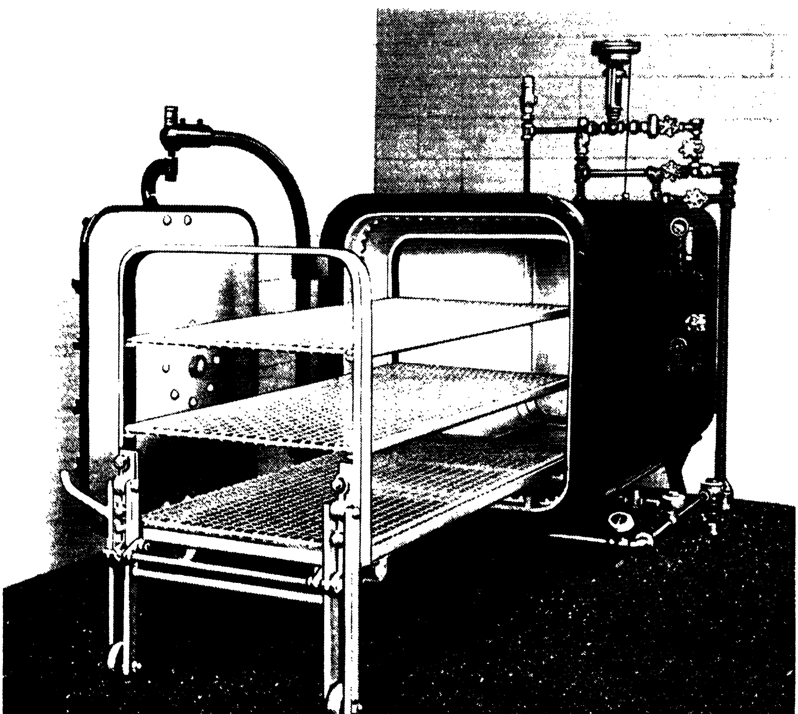


FIG. 23. Bulk sterilizer with drop wheel carriage, shelf type, suitable for mattresses or surgical supplies.

FIG. 24. Typical heavy load of surgical supplies, properly arranged for efficient sterilization. Using a modern temperature controlled machine, the exposure period for this enormous load need be no greater than 30 minutes, at maximum tempera-ture of 250–254 F.

Nickel-Clad Interiors Prevent Destructive Corrosion of Steel Machines. If machines of steel construction are intended for surgical supply sterilization, or sterilization of fluids, it is always best to secure those having inner chambers lined with pure nickel or monel. This relatively new construction permits sterilization of surgical supplies or solutions without danger of destructive corrosion.

METHOD OF OPERATING BULK TYPE STERILIZERS, TEMPERATURE CONTROLLED

1. **Clean out the strainer** on the inside of the sterilizer at the entrance of the discharge outlet daily. Remove all lint, shreds of cotton and sediment until the pores of the screen are open. At weekly intervals remove the plug screen strainer from the inside of the chamber and pour in one quart or more of boiling hot tri-sodium-phosphate (strong solution) to cleanse the interior of the drainage system.

2. **Turn on heat and secure jacket pressure of 15-17 pounds.** Place load in sterilizer. Close and lock door.

3. **When the jacket gauge shows 15-17 pounds pressure,** open valve controlling steam to chamber one full turn. If the discharge system is free and unrestricted, the temperature shown by the thermometer should advance slowly to 250–254 degrees F. Timing of the period of exposure can safely be made as soon as this temperature has advanced to 240 degrees. The interval of time needed to build up this temperature should be about 5–8 minutes. The temperature, 240 degrees, will never be attained unless the discharge system is sufficiently free for the evacuation of essentially all air.

If the temperature does not advance to 240 degrees within 5 to 8 minutes, the sluggish action may be due to a partial clogging of the screen in the entrance to the discharge outlet at the bottom of the chamber. If this screen is clear, there may be a sticky mass of sediment accumulated in the thermostatic valve or the check valve, which should be cleaned out carefully. This sort of stoppage should occur only at long intervals, if at all. The sluggish action may be due to a fatigued thermostatic valve, which should be replaced before the sterilizer is used.

If the temperature does not advance to 240 degrees at all, that is evidence of a closed discharge line, which should be thoroughly cleaned throughout, or it may be due to a defective thermostatic valve, which should be replaced at once.

Under no condition should the sterilizer ever be used unless the discharge temperature has advanced to 240 degrees F. before timing the period of exposure. If the discharge temperature advances barely to 240 degrees F. and does not advance more than one or two degrees higher, while the pressure is maintained at 15–17 pounds, check first the accuracy of the chamber gauge. If this is approximately correct, that will indicate a faulty thermostatic valve—one of those valves which closes off too soon, usually from fatigue. Such valves should be replaced at once. The temperature should always advance within 10 minutes to very close to 250–254 degrees F. when the pressure is held at 15–17 pounds.

4. **Time the Period of Exposure When the Thermometer Indicates 240 Degrees F.** Check this point first with the mercury thermometer, then with the recording thermometer, if one is provided. Care must be exercised to regulate the pressure so that maximum temperature of 250–254 degrees F. is maintained.

5. **Recommended Periods of Exposure.** See chapter IX for loading.

Mattresses lying on edge or flat on shelves, one mattress to each shelf	30 minutes.
Dressings in normal size packs in double muslin covers	30 minutes.
Moderately loaded drums with double muslin liners	30 minutes.

Fully loaded drums with double muslin liners	45 minutes.
Utensils, nested, in double muslin covers	15 minutes.
Utensils, single, in double muslin covers	10 minutes.
Instruments wrapped for storage	15 minutes.
Rubber gloves in double muslin wrappers, not stacked	15 minutes.
Transfusion or intravenous sets or catheter trays	15 minutes.
Solutions (2000–3000 cc flasks—thin glass)	20 minutes.
Solutions (1000–1500 cc flasks—thin glass)	15 minutes.
Solutions (500 cc flasks—thin glass)	12 minutes.
Solutions (125–250 cc flasks—thin glass)	8 minutes.
Solutions (50 cc flasks—thin glass)	6 minutes.

6. **Exhausting Steam from Chamber for All Materials Except Solutions.** Close valve admitting steam to chamber. Open valve which exhausts steam from chamber and when chamber gauge shows zero pressure, open valve which controls the ejector and leave it open for a period of 10 to 15 minutes depending upon the size and density of the load. During this period the chamber gauge will show some minor degree of vacuum, of no significance since the drying effect comes from the residual heat in the load and the heat from the hot jacket. Rapid evacuation of vapor prevents reabsorption and leaves the chamber relatively free from vapor and odors so that there will be no appreciable escape when the door is opened. If appreciable vapor escapes when the door is opened, that indicates too short a period of drying. To open the door, close the valve controlling the ejector and wait until vacuum has been broken, a matter of two or three minutes.

7. **To Cool Solutions Following Sterilization.** At close of period of exposure, close valve admitting steam to chamber. Very slightly crack the valve which exhausts steam from the chamber and watch the chamber gauge, so regulating the exhaust of pressure from the chamber that a period of not less than 7 minutes is taken to reduce chamber pressure to zero. This period should not exceed 10 minutes. Remove solutions at once.

8. **Clean Out the Sterilizer Daily.** Because these machines are so large, much lint and sediment will accumulate in the sterilizer and it is advisable always to wash them out daily before heating up. If necessary scrub with a stiff brush.

9. **When Interior of Plain Steel Surfaces (Not Nickel or Monel Lined) Show Signs of Corrosion.** Nickel or monel lined interior surfaces require no attention other than routine flushing with water. Plain steel machines will rust, especially on the bottoms. When rusting or corrosion is noted, a mechanic should be required to scrape down the corroded surfaces and cover them with a good grade of aluminum, bronze or other suitable finish as recommended by the manufacturer.

CHAPTER VII

How Dressings Are Dried After Sterilization and Definition of Common Causes of Wet Dressings.

If dressings are delivered from the sterilizer soggy with water, so wet that a few minutes exposure in the air does not dissipate the moisture, they should be thoroughly dried out by some external means and resterilized. In a moist soggy condition, there is always danger that outside impurities will be conducted through the wrapper by water seeping through. Similarly if sterilized dressings become wet after removal from the sterilizer, they should be discarded as unsterile. The usual muslin wrapper will filter out dust from air drawn in but it cannot filter organisms from water.

We approach the problem of drying dressings by simple analysis of physical laws which govern the process. Understanding of these laws will usually direct the operator to solution of drying difficulties.

While dressings are undergoing sterilization, every fibre of porous fabrics is saturated with moisture, the condensate left in the goods as heat is absorbed from the steam which permeates them. This moisture, finely dissipated through the mass, is heated to the same temperature as the surrounding steam, about 250 F. This condition will prevail at the close of exposure but immediately when pressure reduces, with the exhaust of steam, there is a tendency for the moisture to flash into steam or vapor, occasioned by the residual heat in the goods—above the boiling point of water, and the heat conducted to the goods from the hot steam jacket. The real drying process then resolves itself into the detail of getting rid of the vapor as fast as it forms.

In this respect operators have been trained for years to believe that creation and maintenance of some minor degree of vacuum would bring about excellent results but that principle is faulty, for with rare exceptions the greatest degree of vacuum possible to attain does not exceed 10″ of mercury as indicated by the chamber gauge. That would mean 10–30 or just one third of the vapor eliminated from the chamber, and maintaining vacuum after it is attained is an utter waste of power and time, an expensive procedure. There are three well known systems of drying in common use,

any one of which will give reasonably good results in so far as actual drying is concerned.

Perhaps the simplest method known is to exhaust the steam from the chamber to zero pressure, leaving the jacket pressure on to keep the walls of the chamber hot. When chamber pressure has been exhausted, unlock the door and crack it very slightly, just enough to permit vapor to escape. This will provide what is known as a chimney effect in which room air will enter at the bottom of the door while vapor or steam, mixed with this air, will escape at the top of the door. A lighted match held at the bottom of the door will demonstrate this draft effect. The flame from the match will be drawn in sharply. If the goods have been properly sterilized otherwise, an interval of 5 to 10 minutes will usually suffice to dry the load satisfactorily. So far as drying is concerned, no more effective method is available. Unfortunately, all the steam or vapor will escape into the room, a most serious criticism if rooms are poorly ventilated. This is the system followed with all sterilizers not equipped with vacuum creating valves.

The second method is a combination of the old so-called vacuum system and the "cracked-door" process described above. Pressure is exhausted from the chamber to zero, then the operating valve is turned to the vacuum position for a limited time only (3 to 5 minutes). In this period the vacuum valve will exhaust about all the vapor it is capable of handling. Then the vacuum is broken and the door is unlocked and cracked just enough to permit the remainder of the vapor to escape. By this method only ⅔ of the vapor will escape into the room as with the simple "cracked door" method. Otherwise the results will be identical.

The third system is relatively new. It involves the principles of both the older methods but exhausts practically all vapor to the vent. The vacuum device is built into the operating valve and is used in this unique way: Following sterilization, pressure is exhausted to zero, then the operating valve is turned to the vacuum position, but instead of merely creating a vacuum, the device is used as a pump to circulate filtered air to the chamber where it entrains with the vapor and both are discharged to the vent. Under this system, when the door is opened, there is no noticeable escape of vapor. Drying usually occupies a period of 5 to 10 minutes and the drying effect is quite satisfactory.

Common Causes of Wet Dressings

If the sterilizer is functioning properly in other respects, any of the above methods of drying will be found perfectly satisfactory. If any of these methods is followed carefully, and the dressings are

found wet, some other cause than the drying process must be located and corrected.

If the air and condensate discharge system has become foul with sediment and is clogged, or if the thermostatic valve or check valve fails to open so that there is no free discharge passage-way from the chamber, condensation will collect in the bottom and the goods will not be dried out properly. This fault will be indicated by water lying in the bottom of the sterilizing chamber when the door is opened. If no water is found in the bottom of the chamber but if the bottom tier of dressings is perceptibly wet, that will indicate a sluggish performance of the discharge system. In either event call a mechanic at once to clean out the line, and to check the performance of the thermostatic valve.

Soggy, wet packages should never be placed in the sterilizer for drying. They will not dry out in a relatively brief drying interval. They should be dried out by some other means before being placed in the sterilizer.

When the direct steam method of heating is used, an improperly drained steam line, supplying steam to the sterilizer may deliver water to the sterilizer instead of steam. If this fault is pronounced, both the jacket and the chamber are filled with water, and of course the load will be saturated. There is only one cure for this difficulty. The steam supply line must be adequately drained before it reaches the sterilizer by a properly trapped bleeder line, so this condensation will be carried away. Then this line should deliver essentially dry steam to the machine. Many steam lines are not properly installed in this respect, but there is always some means of correcting such errors.

An indication of water in the supply line or a clogged return trap from the jacket of the sterilizer, is a loud hammering noise which occurs when steam is turned to the sterilizer to heat it up. There is grave danger under such conditions of saturating the load with water, and no attempt should be made to sterilize until the difficulty is corrected. It always can be corrected.

Quite frequently, the jacket return trap will stick—remain closed—in which event the jacket will fill with water, then the return trap should be cleaned or replaced, as investigation may indicate. Loud hammering noises will invariably indicate this condition.

If the boiler or steam generator type sterilizer is used, heated by gas, electricity or steam, wet dressings are sure to follow the overfilling of the boiler with water. This may occur through carelessness of the operator in not shutting off the filling valve when the proper water level has been reached, or it may occur by slow leakage of the water filling valve.

If for any reason, the boiler has been filled until the level cannot be seen on the gauge glass, the water should be drained from the boiler until the level is about half an inch from the top of the gauge.

Never place goods in the sterilizer so that they will be in contact with the door when it is closed. During sterilization the inner surface of the door is constantly covered with a thin film of condensate, and any porous materials which contact it will absorb this moisture.

Never place instruments in jars or other closed bottom receptacles in the sterilizer unless the receptacle is freely open at the top. The receptacle must be placed on its side in a manner such that all condensate will drain out freely, and so that it cannot pocket air. Test tubes containing instruments, closed with cotton stoppers, for example, must always be placed on their sides.

A somewhat uncommon cause of wet dressings is a sterilizer so improperly installed that the back end is lower than the front end. In that event, condensate will drain naturally to the rear and the wet vapor forming from it will saturate the goods. This can easily be corrected by adjusting the supports, preferably so that the front end is slightly lower than the rear end.

The method of loading heavy packages of porous materials has a great deal to do with the speed and effectiveness of drying. As covered by chapter IX, steam will permeate heavy flat packages much more effectively and rapidly when they are placed in the chamber on edge, rather than flat side down. Similarly, the wet vapor from such packages will escape more readily when the packages are placed on edge.

Chapter VIII

The Pressure Steam Sterilizer for the Laboratory (Laboratory Autoclave)

This type of pressure sterilizer operates upon essentially the same principle described for surgical sterilizers in preceding pages. Usually the sterilizer is not steam jacketed since the average requirement of the laboratory does not necessitate any drying process. The method of valving is different but the same principle of air evacuation and temperature measurement are followed precisely. There is a tendency in recent years to use steam jacketed machines because there is some demand for sterilization of dressings, syringes and needles wrapped in muslin and other articles requiring a drier process. In either construction, the same method of valving is required as that shown by Fig. 25.

In other respects the performances of the two types of machines are identical. For many years the performance of nearly every laboratory sterilizer has been measured by a pressure gauge and a thermometer, mounted at the extreme top of the sterilizing chamber, with rather obvious inaccuracies. As previously explained, the temperature developed in the sterilizing chamber is directly dependent upon the degree of air elimination from the chamber. Pure hot steam will float immediately to the extreme top of the chamber and the cooler air will naturally gravitate to the lower areas. After a considerable time the steam will penetrate and mix with the air and ultimately uniform temperature will result which will reflect the percentage of air content. Measurement of temperature at the top of the chamber will therefore be highly misleading, unless the air discharge from the chamber is essentially complete.

The only dependable method of gauging the performance of the machine is by measurement of the temperature in the discharge system, just the same as for the surgical supply sterilizer. In that location, the thermometer will serve as a direct gauge of the performance of the all-important air discharge system, and it will indicate the true internal temperature in which the operator is interested.

One test case will serve to amply illustrate the unreliability of the thermometer installed in the top of the chamber. A laboratory sterilizer was tested with an accurate potentiometer. Pressure was maintained at 15 pounds and the thermometer indicated 248 degrees F. promptly and with little fluctuation. The temperature developed in

a small flask of water rose only to 220 degrees after thirty minutes. Investigation disclosed that the discharge line was almost completely clogged with sediment.

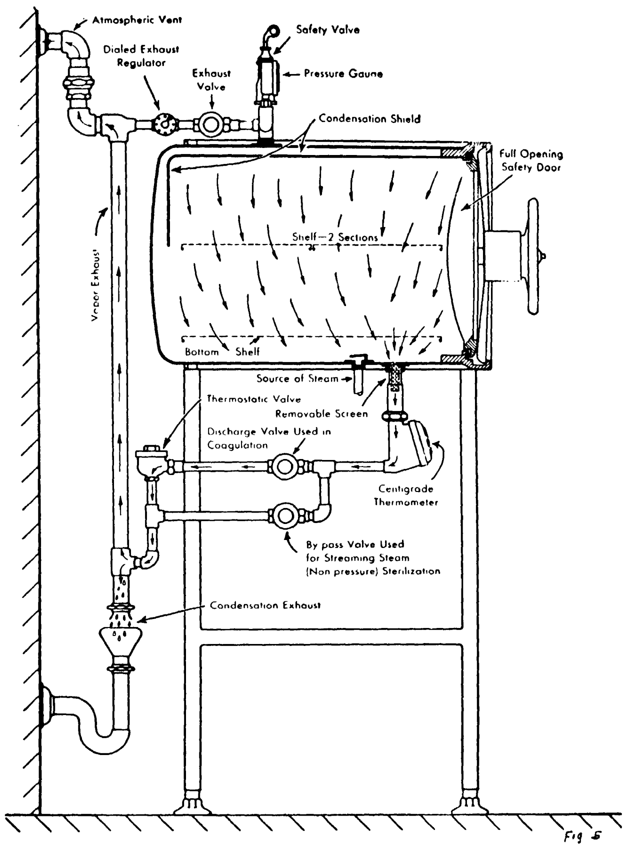


FIG. 25. Typical diagram of single wall laboratory sterilizer showing various operating parts. The valving is adapted to every conceivable requirement of the sterilizer.

The discharge system was then cleared and the test repeated. The thermometer indicated almost identical temperature but the temperature in the small flask of water advanced to 250 degrees F. in twelve minutes. An accurate thermometer in the discharge line would have promptly indicated the trouble, unmistakably. There would have been no appreciable advance in temperature at all, when the drainage line was clogged.

It will often be found that the commonly used commercial thermometers are considerably inaccurate at least at some part of the scale. An examination of several stock instruments at one time showed variations of 5 to 8 degrees at the critical range. In securing these instruments or in purchasing sterilizers equipped with them, care should be taken to specify "mercury type" thermometers, guaranteed accurate within one degree at the range 240–250 degrees F. (115–121 degrees C.).

Coagulation and Sterilization of Blood Serum. This is one of the difficult performances required of the laboratory autoclave in which it becomes necessary to greatly prolong the exposure period, with

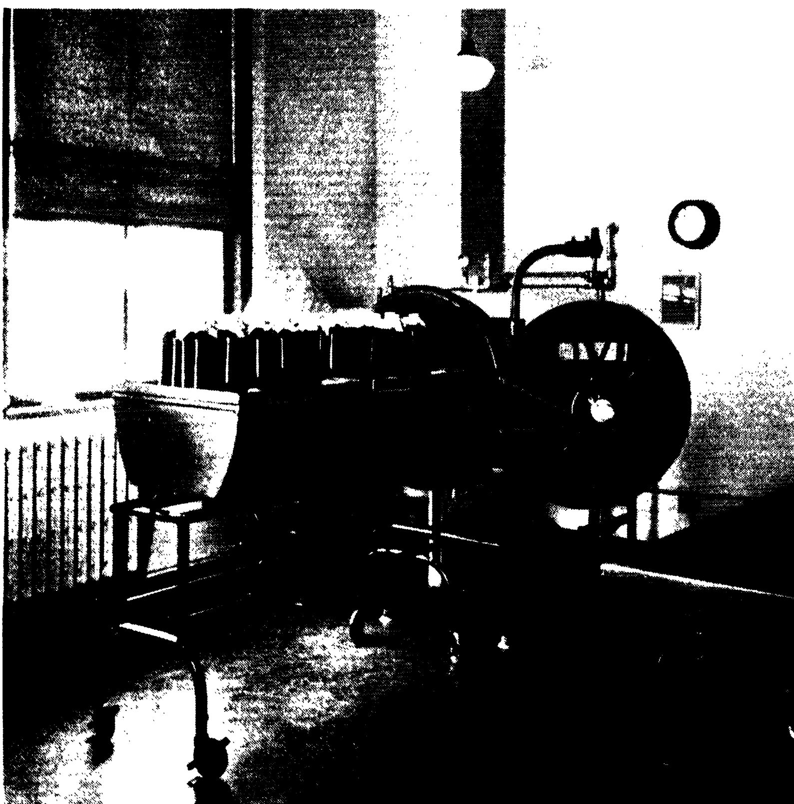


FIG. 26. Typical large laboratory sterilizer adapted to requirements of bulk sterilization in commercial laboratories or for solution sterilization in very large hospitals.

absolutely no elimination of air from the chamber. Otherwise bubbles will form in the media. The process is as follows:

With pressure adjusted to maintain 15–17 pounds pressure, place racks of slants in sterilizer, preferably supported near center of chamber on some form of non-heat-conducting material such as a wood shelf (swamp cypress). Close and lock the door. Close the exhaust valve. Close the by-pass and shut-off valves in the drainage system from the bottom of the chamber. Then only, turn on the heat and maintain the pressure at 15–17 pounds for ninety minutes. The thermometer will not indicate temperature rise because the

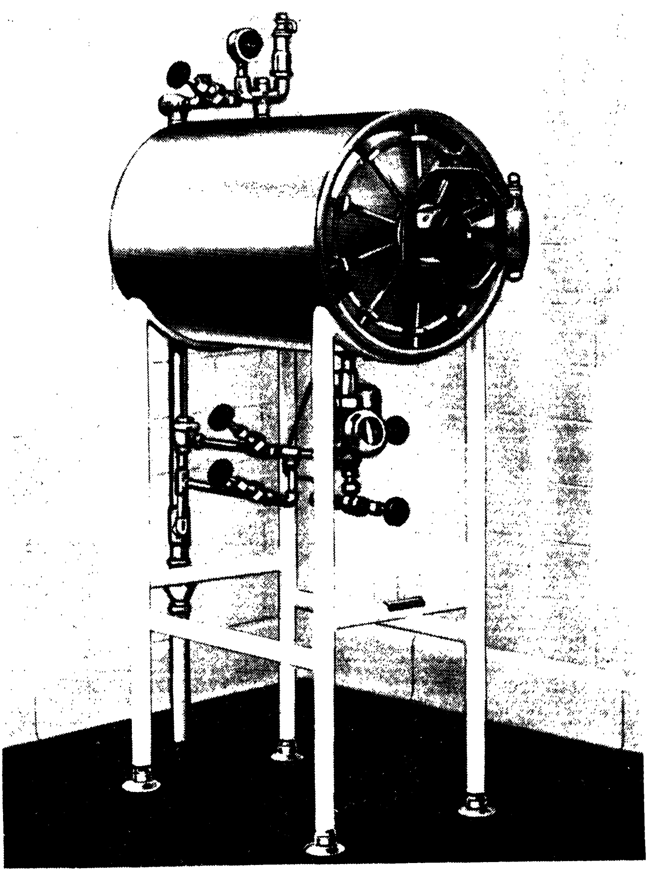


FIG. 27. Steam heated laboratory autoclave—single wall type.

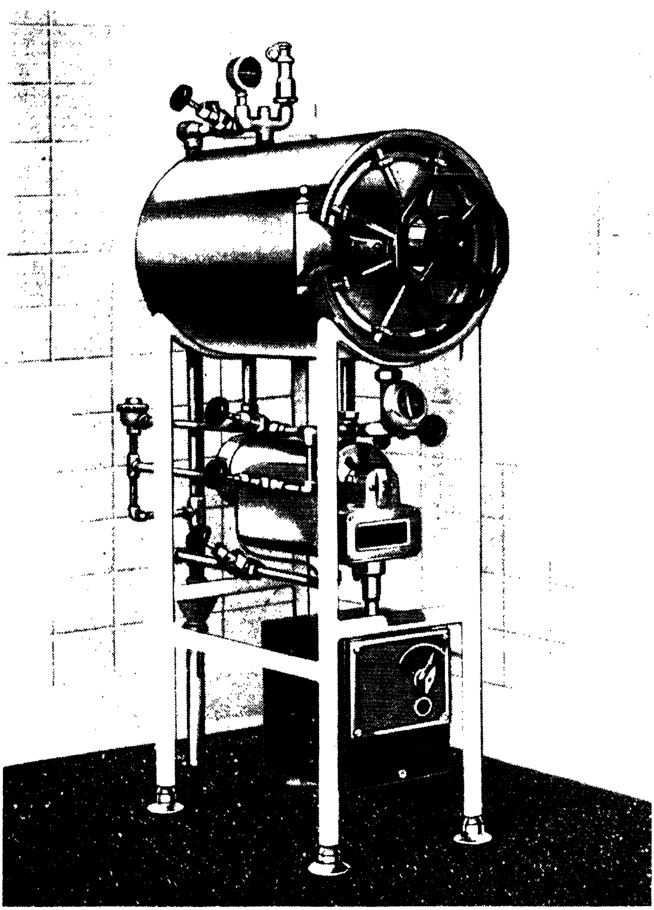


FIG. 28. Electrically heated laboratory autoclave—single wall type.

chamber discharge system is closed. At the close of the ninety minute period, turn off all heat and permit the machine to cool down until the pressure gauge shows zero pressure. Then only, open the shut-off valve in the chamber discharge system to discharge condensate from chamber before opening the door, a matter of two or three minutes.

This will produce smooth slants. Sterilization is a product of relatively reduced temperature applied for the abnormal period of exposure, a total period of about two hours.

Oversterilization of Media is a Common Fault. The writer is con-

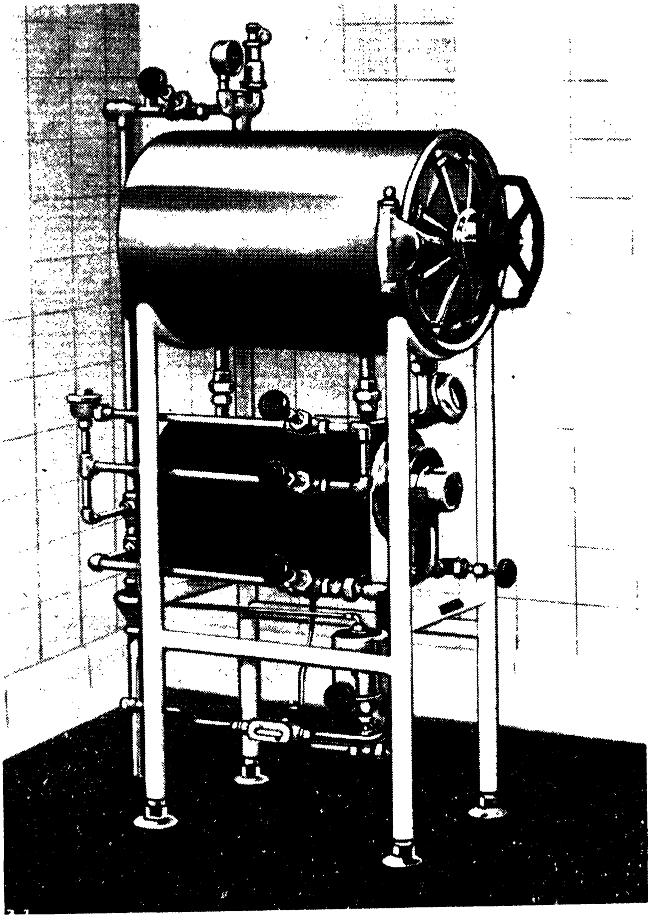


FIG. 29. Gas heated laboratory autoclave—single wall type.

vinced from much observation that quantities of valuable supplies are destroyed or at least injured by unduly prolonged sterilization in efficient machines or perhaps by necessarily prolonged exposure in highly inefficient machines of the slow heating variety.

Exposure Should Be Timed to Correspond With the Individual Flask or Tube. Assuming that a modern sterilizer is in use, destructive effects follow the incorrect practice of sterilizing all loads for the same period, the old "15 pound, 15 minute" rule or something equally unscientific. Tests expose the fault of this practice in unmistakable terms. It takes much longer to sterilize a 1000 cc. flask

of fluid than perhaps 15 cc. of fluid in a test tube, yet it is not uncommon to find the sterilizer filled with large flasks and small tubes or flasks. For example, we were asked to explain why procaine was being destroyed in one hospital. It was put up in small bottles containing two ounces and was being sterilized in the same chamber with 1000 cc. flasks of saline for 20 minute exposure. Tests indicated that exactly the same sterilizing influence was exerted on the procaine in 8 minutes that was found in 20 minutes exposure of the saline.

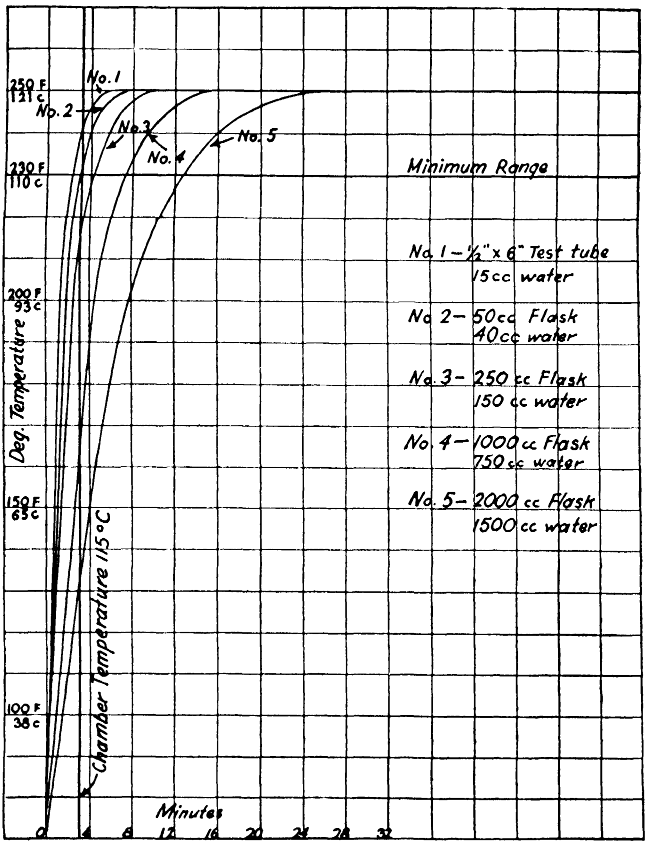


FIG. 30. Temperature curves showing the time required to heat various sizes of Florence flasks, using a modern temperature controlled autoclave regulated to maintain 121–123° C. maximum. Note particularly that all such performances should be timed when the thermometer indicates 115° C. as a starting point. In this way the machine becomes a precision apparatus. The same results may confidently be expected every time the machine is used.

To clarify this point a series of carefully conducted tests was made (Fig. 30) in which various sizes of flasks were sterilized to show proper timing of exposure. It should be noted that in these tests, the sterilizer was carefully regulated to maintain a maximum of slightly more than 121° C. These curves will furnish a suitable basis for the establishment of periods of exposure for routine work.

Size of Individual Flasks, Not The Number of Flasks, Determines Period of Exposure. In sterilizing loads contained in flasks of uniform size, the exposure period will not need to change regardless of how many flasks may be contained in the sterilizer, because every flask will be subjected to the same kind of steam. Of course the sterilizer will use more heat for a large load than for a small one and the time required to build up to the initial temperature (115 C.) as indicated by the thermometer will vary with the load but the measured exposure should not change.

One other interesting point should be noted. Florence flasks are nearly spherical in shape. One-half filled or completely filled they will require the same time to heat, but if such a flask is two thirds filled, it will heat noticeably slower. About 25 to 30% more time is required. This is due to the fact that heat is absorbed by the fluid at a rate dependent upon the exposed area of that part of the flask containing fluid. Half filled, roughly half the area is exposed to heating but entirely filled, about twice the area is exposed. Adding 50% to the fluid in the half filled flask, adds only a small amount of exposed area, relatively. On the other hand, any straight sided bottle or flask or tube will heat up in the same time regardless of the amount of fluid contained since the exposed area increases or decreases at the same ratio with the quantity of fluid.

Slow Heating, Obsolete Types of Autoclaves Are Often Responsible for Destruction of Heat-Sensitive Fluids. Our attention has been called to various failures which have been somewhat difficult to analyze at times. Many solutions are not only sensitive to excessive temperatures but also to prolonged maintenance of relatively moderate temperature. One example will serve to illustrate the point perfectly. The writer saw an autoclave opened and a dozen flasks of expensive, hard to secure, media removed—all ruined. Investigation disclosed that the pressure had been maintained at 15 pounds for 15 minutes, but a period of one full hour had been required to build up to that pressure. The temperature had been increasing from room temperature to roughly 121 C. for one hour and that temperature had been maintained for another fifteen minutes. The destructive action was undoubtedly due to the prolonged heating-up period. A modern sterilizer with suitable heating equipment would heat up in about 10 minutes.

Another example of the effect of prolonged heating is found in the too-slow cooling down of the autoclave after sterilization, almost as serious as slow heating. It is sometimes the practice to turn off all heat and let the sterilizer cool down to atmospheric pressure after sterilization. Usually that process will require about half an hour during which the fluid will be held at temperature ranging from the boiling point of water to the maximum attained, and any heat-sensitive fluid must react to that prolonged heating.

The proper way to cool down the sterilizer after sterilization is over is to regulate the exhaust valve so that pressure will reduce to

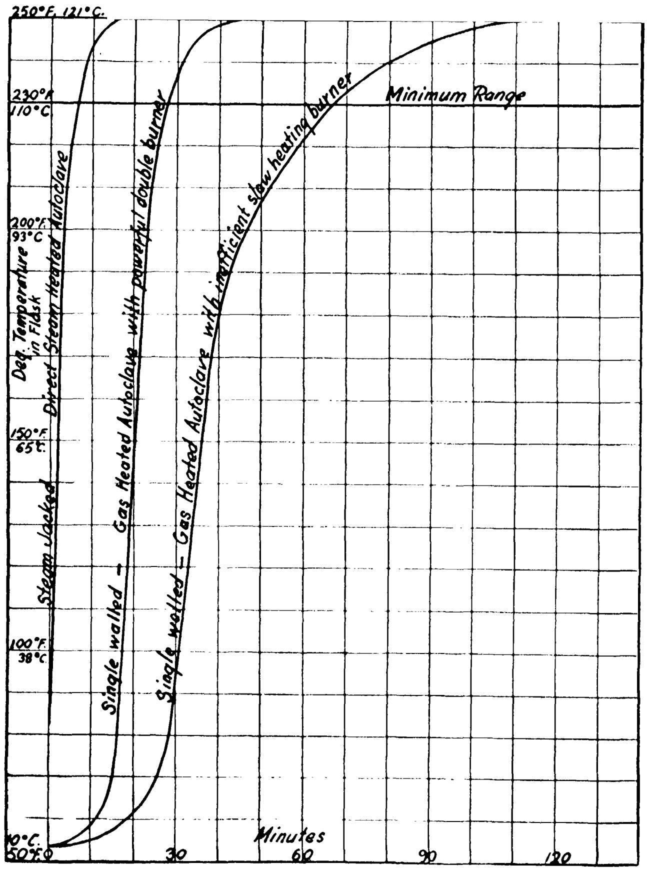


FIG. 31. Temperature curves illustrating the sterilizing effects of rapid and slow heating autoclaves. Long drawn-out sterilization is responsible for the destruction of heat-sensitive media.

zero at a uniform rate in not less than 6 or 7 minutes nor more than 10 minutes. This will give the fluid time to loose its heat at the same rate as the surrounding steam without violent ebullition.

Many of the older autoclaves still in use are notoriously slow in heating, are equipped with presumably cheaper and less powerful units. The point is illustrated in Fig. 31.

Proper Timing of Exposure to Suit the Container Usually Eliminates the Need for Fractional Sterilization. It is undoubtedly due to failure to recognize this fact that so many laboratories routinely sterilize many fluids by the fractional method. There are perhaps some forms of media which will not withstand the normal temperature of the autoclave but these are limited to a very few relatively.

The Director of Laboratories in a famous medical school recently told the writer that all of his routine work, much of which had previously been done by the fractional method, is now being autoclaved by proper consideration for timing with perfect results. He now uses the fractional sterilizer only for teaching purposes, to demonstrate the principle of fractional sterilization.

CHAPTER IX

Setting Up Standards for Surgical Sterilization. Regulation of the Sterilizer. Definition of "Period of Exposure." Preparation of Various Materials for Sterilization.

The year 1933 saw the beginning of an entirely new era in Surgical Sterilization. Then, for the first time, sterilizers were provided with which operators could routinely measure the temperature, the true bacteria-destroying potency of the steam, so that any and every prescribed performance could be duplicated with precision, over and over again.

This rather remarkable approach to perfection in the performance of modern precision sterilizers has demanded a radical revamping of nearly all sterilization standards which had been set up around apparatus of recognized inefficiency and it is somewhat difficult for operators trained under the older standards to appreciate fully just what is implied in the term "precision." Comparison between the older pressure controlled and the modern temperature controlled sterilizer can be likened properly to the prescribing of some drug at full strength as opposed to the use of the same drug of unknown dilution. With the temperature controlled machine we use full strength steam but with any pressure controlled sterilizer it is always uncertain how much the steam may have been diluted with air, so to be reasonably certain of sterile results, our older standards recognized this fault and prescribed periods of exposure and pressure ranges which now need overhauling.

If, in using our modern efficient machines, we continue to sterilize bulk loads at 20 pounds pressure for one hour, the almost universal practice under the older system, we most assuredly shall cause premature disintegration of nearly all surgical supplies—muslins, linens, gauze, all forms of dressing materials. In addition, a great deal of time will be literally wasted. The economic factor cannot be ignored.

Setting up new standards around the use of the modern precision sterilizer requires considerable analysis and thorough understanding and application of fundamentals which will now be taken up in proper sequence.

Minimum Requirements for Surgical Sterilization with Pressure Steam

We now have authentic information on this subject published in the December 1938 Journal of Bacteriology, the official organ of The American Society of Bacteriologists. These data are used throughout this text in the determination of periods of exposure for various prescribed loads and in prescribing proper regulation of the sterilizer. Summation of the results secured during this investigation show:

> Typically resistant, surgically significant (pathogenic) spores such as C. tetani, C. welchii, C. oedematiens are destroyed (in direct contact with steam) at:
>
> 110° C. (230° F.) in 10 minutes
> 115° C. (240° F.) in 4 minutes
> 121° C. (250° F.) in 1 minute

In using these data, however, in prescribing periods of exposure for various loads, tests are invariably made to denote performance that will carry a considerable margin of safety, so that in no case do we suggest any close approach to the minimum requirements. A typical test chart by means of which periods of exposure have been set up is shown in Fig. 32. Readers are urged to study this chart

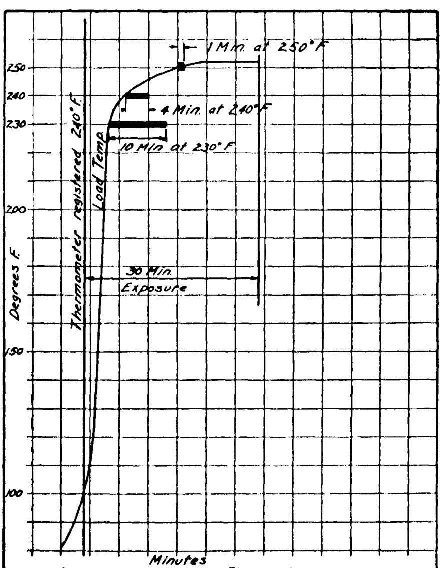


Fig. 32. Typical test chart showing steam permeation through a properly prepared surgical pack. The curve indicates temperature measured in the heart of the pack as the period of exposure progresses. The temperature was measured by a potentiometer having its thermocouple located in the center of the pack. The heavy horizontal lines denote the minimum periods of exposure for sterilization at 230, 240 and 250 F. as quoted above. The timed period of exposure is measured from the point when the thermometer indicates 240° F. The maximum temperature developed in the load is only slightly above 250° F. The margin of safety is indicated not in excessive temperature but in exposure well beyond the minimum requirements.

carefully to gain a thorough understanding of how basic information relating to steam penetration through porous supplies is secured and applied.

What "Direct Steam Contact" Means. This is a detail of great importance which must be thoroughly understood in order to avoid attempt to sterilize in steam any product where "direct steam contact" is impossible or perhaps difficult. All steam sterilization functions are based upon the supposition that the steam can and will contact every fibre or particle of the substance undergoing sterilization. The bulk of the average surgical load is made up of fabrics of one kind or another, gauze, cotton products, linens, etc. In sterilizing them, correct performance assumes complete permeation of the entire mass with the heat and the moisture of the steam. In fact it is impossible in any normal operation to heat these porous products in the autoclave without bringing in the moisture factor since heating of them is accomplished by the process of condensation in which the fibres are saturated with moisture as heat is abstracted from the steam. See Chapter II—The Condensation process of heating with saturated steam.

In sterilizing instruments and utensils or other metalware, a similar process takes place except that in this case there is no permeation of the metal of course, since only surfaces require sterilization. The surfaces however, are drenched with moisture as the metal is heated to the temperature of the surrounding steam.

Such products as bone wax, various oils, vaseline, talcum powder in cans or jars, cannot be sterilized completely in the autoclave because it is impossible to bring about "direct contact" of the steam except for exposed surfaces. Heat will gradually be absorbed through any such mass and the equivalent condensate will deposit on the surfaces but no moisture permeates the substances. The heat of the autoclave, lacking the moisture factor, will not be adequate. Organisms buried or sealed in the mass will not be killed and when such materials are left in the body tissues, they will grow and cause infection when the tissues have absorbed the wax or oil or vaseline in which they are encapsulated. These materials must be sterilized in the hot air oven as discussed in another chapter.

Another example of failure to bring about "direct steam contact" in the autoclave is found in the attempt occasionally to sterilize hypodermic needles or other delicate instruments in test tubes with the ends tightly closed with rubber or cork stoppers. The heat absorbed through the glass walls would hardly be sufficient to destroy the least resistant of the organisms. The test tube idea of protecting the instrument is excellent but the tube must be closed with nothing more restrictive than a cotton plug and the tube must rest on its

side in the sterilizer so that air can escape, permitting the steam to enter.

Aqueous fluids are the only exception to the rule of "direct steam contact" and in that case, we have the moisture factor in the fluid so that it is necessary only to absorb heat from the surrounding steam.

Regulation of the Sterilizer. As outlined above, authentic data indicates that the most resistant pathogenic organisms are destroyed in direct contact with steam in 10 minutes at 230 F., in four minutes at 240 F. and in one minute at 250 F. Upon analysis it becomes immediately apparent that 240 to 250 F. is a highly potent sterilizing range, that there is little purpose in maintaining temperature higher than 250–254 F. because sterilization occurs almost instantly at this range. There are excellent reasons for limiting the temperature to this range. It has been shown conclusively that about 250 F. may be considered as the critical temperature for most surgical supplies. Exposure to temperature materially higher brings about more or less speedy disintegration and even at this range it is necessary to restrict the period of exposure for rubber goods to 15 to 20 minutes, else they will withstand only a few trips through the sterilizer. Coarser fabrics also react badly to higher temperatures or prolonged exposure, more slowly perhaps but none the less surely. Browned muslin covers are the direct result of oversterilization. This does not occur in one performance but is the result of repeated over-sterilization and it means a loss to the hospital in premature replacement costs.

We find ample justification from this analysis for fixing the one regulation range for every surgical sterilization performance at 250–254 F. maximum temperature as indicated by the thermometer, corresponding to 15–17 pounds actual steam pressure.

While the pressure gauge must be used for the initial adjustment of the regulated range, it must be borne in mind always that commercial pressure gauges at best are not very accurate and particularly they are not stable. After a little use they frequently become distorted from fatigue, often reading several degrees too high. The writer has never seen one reading too low. With these facts in mind, regulation of the sterilizer should always be checked with the thermometer while the sterilizer is in use, after maximum temperature has been attained. If the temperature does not advance to 250–254 F., regulation should be changed, even if the pressure gauge does indicate several pounds higher than 17 pounds, until the thermometer reading is within the prescribed range.

Because accuracy is of prime importance, great care is exercised in selection of a thermometer of known reliability, one not subject to

fatigue in use. We prefer the mercury type because it can be secured with initial accuracy within one degree at the sterilizing range and because its accuracy is permanent. Vapor-tension, dial type thermometers are sometimes used erroneously because of the readability feature of the large dial. Such instruments are subject to the same fatiguing effect as pressure gauges, may distort many degrees in service. Such distortion is most difficult to detect and it may be serious. We have seen such instruments in use reading as much as 10 degrees high.

Defining "Period of Exposure." Having established temperature regulation of the sterilizer, it now becomes necessary to define what we mean by "period of exposure." Under the obsolete pressure system of control, exposure was usually timed as beginning when pressure had reached 15 pounds. Under temperature control, the period of exposure should be timed as beginning when the thermometer indicates 240 F.

The reason for this range as the starting point should be thoroughly understood. When steam is turned to the chamber for sterilizing, temperature as shown by the thermometer will advance with the initial rapid discharge of air in from 2 to 4 minutes to 240° F., depending upon the size of the sterilizer and the character of the load. Then the rate of advance will slow down at an increasingly slower rate until the maximum of 250–254 is reached. But when the thermometer shows 240° F., the steam surrounding the load will be several degrees higher, close to the maximum. In other words, sterilization is definitely under way. The lag in the thermometer reading behind the actual internal steam temperature is natural and to be expected, and is due to the cooling effect of the thermometer case and to the action of the thermostatic valve which controls the flow of air and condensate from the chamber.

However, knowing that this lag occurs, we must take it into consideration, particularly in sterilizing heat-sensitive loads such as procaine or glucose where even a slight degree of oversterilization may be critical. It is less important in sterilizing bulk loads of coarser fabrics but use of this range as a starting point makes it possible to standardize on an exact procedure for all loads. Just because 15 pounds has always been the recognized starting point in the control of "pressure controlled" sterilizers is no reason at all why in the use of modern sterilizers we should continue that practice. Recall that complete sterilization occurs in 4 minutes at 240° F. in direct contact with steam. This point is being stressed for the reason that many operators still seem to believe that there is something magical about 15 pounds pressure and the corresponding temperature range of 250° F. and insist upon using that temperature as the

starting point. Some of the most exacting sterilizing performances in use today are carried out in industrial plants where every load of goods is subjected to rigid bacteriological tests—at temperature never in excess of about 240 F. The point is—we are prescribing sterilization performances scientifically correct from the safety angle and economically consistent. The hospital has to pay the bills for wasted time in the use of the sterilizer and for power to run the sterilizer, and to replace the goods which will be prematurely destroyed by over-sterilization. Waiting until the thermometer shows 250° F. for the starting point in sterilizing wastes several minutes of well defined sterilizing effect.

How Correct Periods of Exposure for Various Loads Have Been Determined. For all such work we make use of a potentiometer, an extremely sensitive temperature measuring device peculiarly suited to the purpose. The instrument is used with thermocouples which are conducted inside the sterilizer and located at any point where it is desired to learn the temperature. A thermocouple consists of two very fine wires of dissimilar metals (copper and constantan) welded together at the end inserted in the load. The open ends of the couple are attached to terminals on the potentiometer. With every change in temperature at the joined ends of the couple, an electrical reaction occurs which the instrument measures in terms of degrees temperature. The couple is easily conducted into the sterilizer under the door.

Using such instruments we have made literally hundreds of studies in numerous hospitals of all kinds of loads, with the sterilizer always regulated in accordance with data herein, and with the load temperatures timed with the thermometer reading 240 F. as a starting point. In this way we have been able to establish certain fundamental laws with respect to preparation of materials and loading which follow:

Preparation of Routine Bulk Supplies for Sterilization. We shall now explain how air and steam move through the sterilizer, because that movement has a direct bearing on the preparation of packs for sterilization.

All modern sterilizers make use of the gravity system for air elimination in which steam enters the chamber at the back end (see Fig. 34), floats promptly to the top of the chamber, compresses air in the bottom areas, forcing the air from the chamber through an opening at the extreme front end. This assures movement of steam from one end of the chamber to the other and from top to bottom.

Steam Travels in the Sterilizer From the Top Toward the Bottom. Except during the earliest stages of the performance, there will be no rapid movement of air and steam. When the free air in open spaces

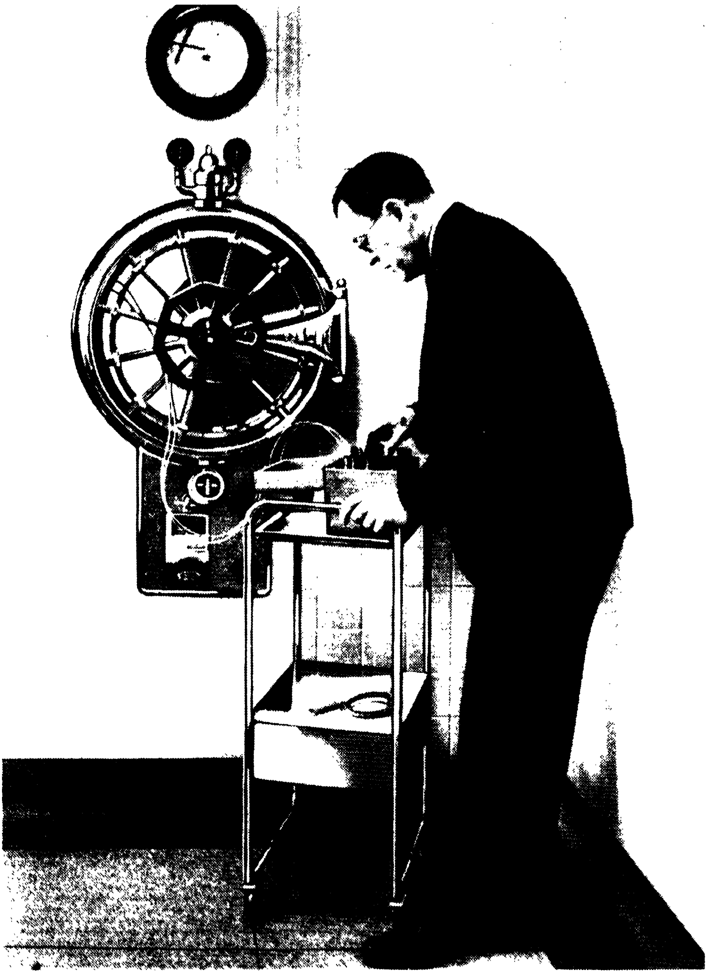


FIG. 33. Illustrating the use of a potentiometer in measuring load temperature during sterilization. The joined ends of the couple are placed in the load at any point where it is desired to measure the temperature. The wires forming the thermocouple pass out under the door, with cellophane insulation, and are connected to the terminals of the instrument. Temperature is read at frequent intervals and the results plotted on graph paper as in Fig. 32. This method of recording permits comparison of tests and immediate analysis of results. Obviously a potentiometer test of every load would be usually impractical, although a very few of our larger institutions do make use of them. The instrument is expensive and delicate but remarkably accurate, invaluable for laboratory experiments as recorded herein.

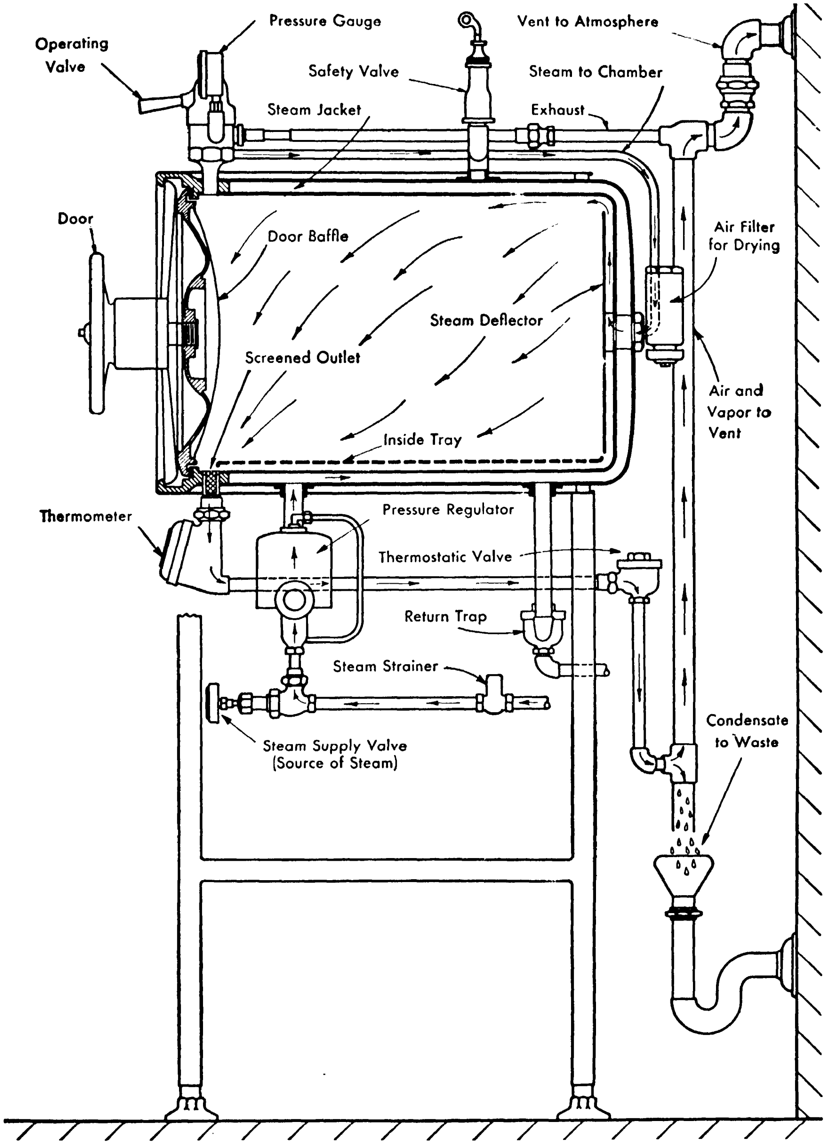


FIG. 34. Longitudinal section of modern pressure steam sterilizer. Steam is delivered from the source to the steam jacket through a pressure regulator which automatically maintains the desired range. The same principle applies for steam heat (as indicated) or for gas or electrically heated sterilizers.

around the load has been driven out, there will be an approach to a static condition of the gases. Pressure will be relatively uniform and the only movement of gases will be occasioned by the slow release of air from the load itself. This is brought about by gravity. Air being heavier than steam will gravitate downward slowly or rapidly, depending upon the density of the packing, and steam will follow as rapidly as the air can escape.

It is obvious that a pack 6″ in depth will present twice as much resistance as a similar pack 3″ in depth, and by the same reasoning, if two packs each 6″ in depth are placed in the chamber in close contact, one immediately above the other, the effect will be the same as if both were wrapped in one pack 12″ in depth. On the other hand, if the upper pack is separated from the lower pack even by a very slight amount, steam will quickly fill the intervening space and attack the lower pack essentially the same as if the two were placed side by side in the sterilizer.

The point which requires emphasis is that the vital discharge of air from the load occurs always in a downward direction, never sidewise, which gives us the background for this basic rule:

> *Prepare all packs and arrange the load in the sterilizer to present the least possible resistance to the passage of steam through the load, from the top of the chamber toward the bottom.*

Assume for analysis a simple package made up from ten pieces of muslin cut into 10″ squares and wrapped together without folding. If this pack were placed in the sterilizer flatside down as in Fig. 35, air within the pack would have to pass through the 10 layers of muslin, plus the cover, in its downward passage. The resistance of

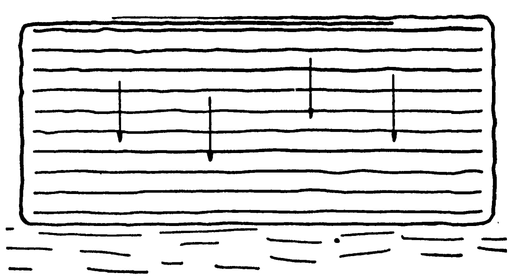


FIG. 35. Packs made up of many layers of fabric placed in the sterilizer horizontally, as shown, are difficult to sterilize because air within the pack must travel downward through the many layers of fabric to escape. Each horizontal layer adds to the resistance and as the outer layers become moist from steam, the resistance is further increased.

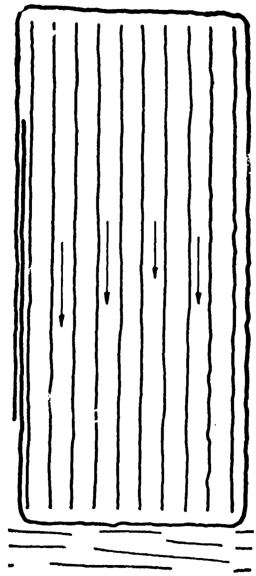


FIG. 36. If the pack shown in Fig. 35 is placed on edge with layers of fabric lying vertically as shown here, air will escape quickly through the tiny spaces between layers. Steam will immediately follow and heat the entire mass in the least time in which it is possible to bring about sterilization.

the dry pack will be increased by the moisture of the steam in contact with the outer layers, further retarding the evacuation of air. Of course, the tighter the weave of the fabric, the greater the resistance.

Now if we place this same pack in the sterilizer vertically as shown in Fig. 36, even though the pack be wrapped fairly tight, there will remain tiny spaces between layers through which air can gravitate toward the bottom with comparative freedom.

This rule will guide the operator in preparing every pack or drum of bulk supplies to be subjected to sterilization and also in the arrangement of the load which will normally be made up of several packs. It is tremendously important when heavy packs are encountered as illustrated by the two temperature curves (Fig. 37). The pack tested in this case (Fig. 38) was abnormally large and dense, but it will serve as an excellent example—for two purposes, to indicate the importance of proper arrangement in the sterilizer and to show the hazards encountered when packs are too large and dense.

Do Not Permit the Use of Abnormally Heavy or Dense Packs. While the temperature curve Fig. 37 shows complete sterilization in 30 minutes when the package is placed on edge in the sterilizer, this by no means justifies acceptance of the pack as suitable. The day of the old fashioned lap set containing everything needed for major surgery should be over. The practice of using large dense bundles

involves too many hazards. The largest pack should not exceed about 12″ x 12″ x 18″ or 20″ in size for routine work. The factors which seem to indicate the desirability of huge lap sets do not offset the safety factor in sterilizing.

When tests indicate that any pack, sterilized by itself, requires more than 30 minutes for sterilization or is barely sterilized in 30 minutes, resting either vertically or horizontally in the machine, that in our judgment indicates the pack is too large and it should be broken down into smaller packs. Materially more than 30 minutes

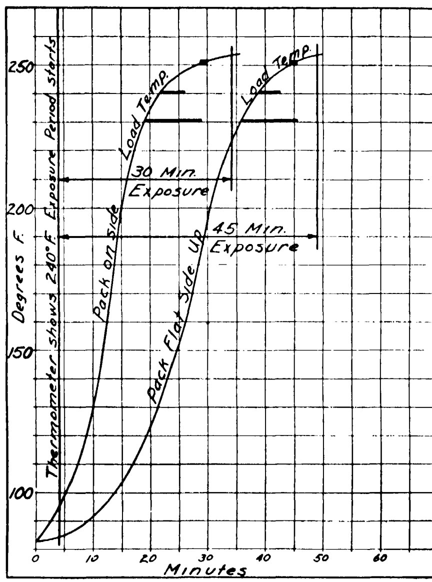


FIG. 37. These two curves showing load temperatures were made with the pack shown in Fig. 38. With the pack lying flat as it appears in the cut, 45 minutes exposure is required to sterilize with a reasonable margin of safety. With the pack lying on edge and subjected to exactly the same sterilizing influence, 30 minutes exposure has produced slightly better than the sterilizing effect of 45 minutes exposure in the other position.

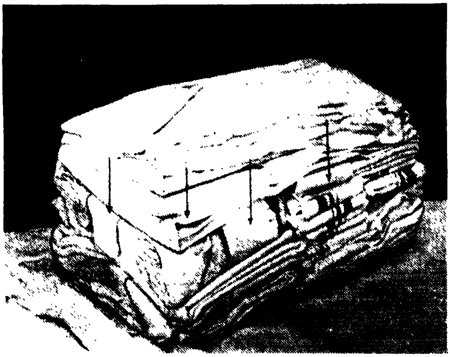


FIG. 38. This is the pack referred to in Fig. 37, an abnormally large and dense pack, much too large and dense to be practical in routine practice. There is always danger, when such heavy packs are used, of interference with other packs in the load, so that a normal period of exposure will be insufficient.

for sterilization in routine work brings about premature disintegration, rotting out of fabrics. The economic factor cannot be ignored because any hospital has a considerable investment annually in replacement of such supplies, at the best. It is our belief that a saving of 5 to 10% in re-placement costs of such supplies, subject to repeated sterilization can be brought about by scientific (controlled) sterilization, as opposed to obsolete methods which have been handed down from those days when sterilizers were known to be inefficient. If the surgery blindly persists in wrapping packs such as shown in Figs. 38 and 39, then the periods of exposure must be prolonged to 40–60 minutes, using the most efficient of sterilizers.

FIG. 39. This package illustrates an arrangement of surgical supplies which should be studiously avoided. Placed in the sterilizer in the position shown, the trays and utensils at the bottom would stop or deflect all downward passage of air from the pack. Even though this arrangement may be very helpful in setting up the surgery, we cannot agree that it represents good practice. Utensils should always be wrapped by themselves.

We have ample justification for this drastic statement in the experience of numerous institutions where the newer methods have proved their value over periods of years. We emphasize the term "controlled sterilization" which seems to be practically possible only where centralized sterilization is carried on as in the modern Central Supply Department. In that event, one group of workers, not necessarily skilled, under direct supervision of one well trained supervisor can maintain precision standards. Normally that is impossible in the busy surgery and the obvious results are experienced. Frequently we find recording thermometer charts showing exposure periods ranging all the way from thirty minutes to one or two hours. The institution pays heavily for such inconsistencies.

To further explain the dangerous element involved in the use of abnormally large or dense packs, suppose there are several of these like Fig. 38 and 39 to be sterilized in one load. If by chance the load is arranged like Fig. 40, the upper packs would retard passage of steam to the lower packs so effectively that a full hour might not be adequate for complete sterilization. But if these packs are broken down into moderate size units, a considerable degree of carelessness in loading could be permitted without jeopardizing the performance, in a thirty minute exposure period.

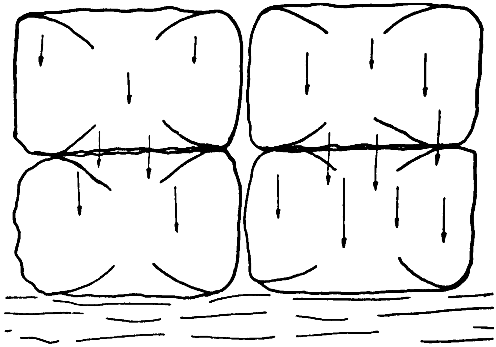


FIG. 40. Abnormally heavy packs arranged in the sterilizer as shown here become doubly hazardous. In effect, the pack is double its normal depth and a period of exposure of at least an hour would be required to be sure of steam penetration through the lower packs.

Arrangement of Loads in Sterilizers. If routine work should demand sterilization of very heavy packs, the operator must take advantage of every possible factor which will aid steam penetration. First, place packs in the sterilizer on edge—never flat side down. There should be no other packs in close contact with heavy packs, either above or below, and separate them from each other as much

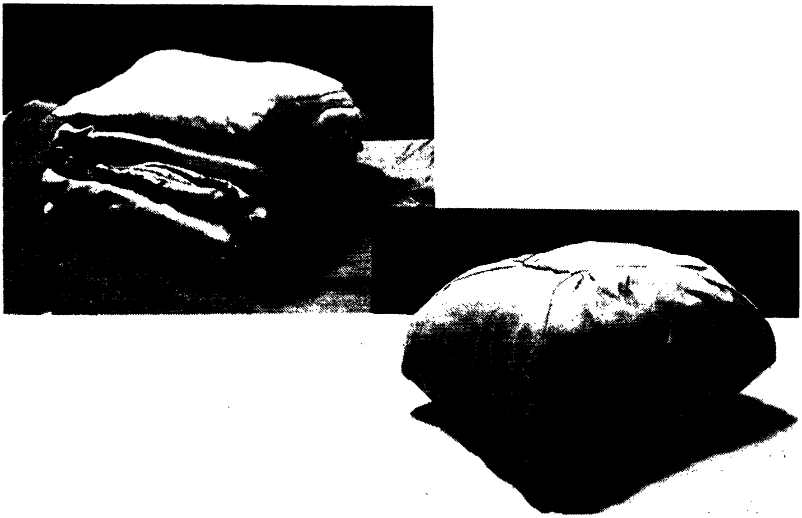


FIG. 41. This pack is well designed for routine sterilization. It contains five gowns and conforms in size to the standard for maximum which has been set up after many tests, 12"x12"x20".

as possible, so there is some slight space free for steam contact on all sides. Emphatically, do not compress them into a tight mass. In very large shelf type sterilizers (Fig. 43), do not permit the load to entirely fill the spaces between shelves, for that open space is the passageway for steam. Properly arranged loads in these huge sterilizers will sterilize quite as effectively as in small sterilizers. Strange

FIG. 42. This maternity pack was arranged with great care to keep within the prescribed limits for size, providing at the same time a practical grouping. The pack is 12"x12"x20" and contains: 2 sheets, 2 triangular dressings, 4 towels, 12 cotton sponges, 1 perineal dressing, 1 umbilical cord dressing, 1 one-yard pack, 20 clinic dressings, 3 table covers.

as it may seem, the size of the sterilizer or the amount of material in the sterilizer is not the determining factor in fixing the period of exposure. The exposure must be determined initially by the size of the largest and most compact pack in the load. Then if these packs are arranged so that they have free access to the steam, it does not matter whether the sterilizer contains one pack or fifty. The only factor subject to change under that condition will be the time required to build up temperature to the sterilizing range, as indicated by the thermometer. With a very heavy load, the temperature will build up a little more slowly.

Figs. 41 and 42 illustrate well designed heavy packs, as heavy as should be permitted normally. These packs were arranged after much study in one of our large University Centers where facilities were at hand for thorough investigation.

In placing heavy loads in smaller (cylindrical) sterilizers, the same problems exist and it is more difficult to meet them than with the larger shelf type sterilizers. The operator must make sure that adequate steam spaces are provided between packs to assure conduction of steam to the lower areas. It is best to place the heavier packs on edge in the bottom tier, being sure that they are not compressed tightly together. There should be no more than the one tier of the heavier packs and anything stacked above should be light and preferably arranged crosswise like cordwood and very well separated. If this is done carefully, without crowding, there will be little interference in steam penetration to the lower goods from those on top. It is well to remember that any steam space at all, even so little as ¼" will permit free conduct of steam, which accounts for our frequent reference to the need for separating packs from each other. Fig. 44 illustrates the cordwood principle of loading.

Purpose of the Perforated Metal Tray in the Bottom of the

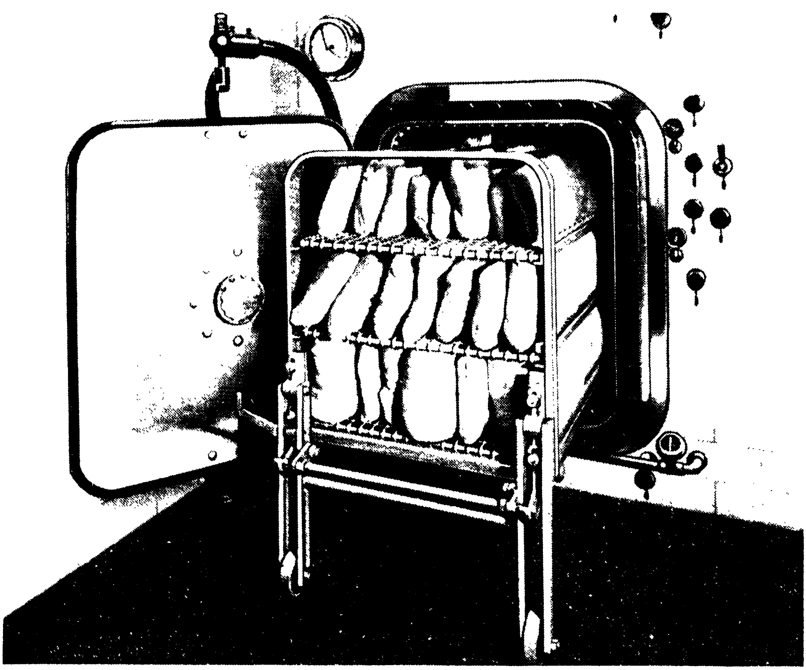


FIG. 43. This picture was made of a routine load in the Central Supply of a prominent University Center. If loads of this kind can be safely sterilized in 30 minutes exposure, it is certain that every hospital can set up similar standards quite as successfully. Note the arrangement and particularly note that no pack is larger than about 12"x12"x20".

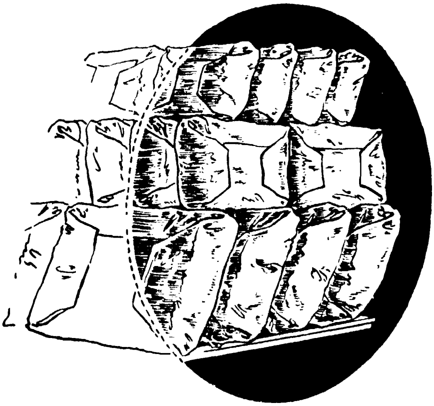


FIG. 44. This cut illustrates the cordwood arrangement of packs in a cylindrical sterilizer to promote a free circulation of steam. Place the heavy packs on the bottom of the chamber being most careful not to crowd them closely together. Place only light packs above and alternate layers should be crossed as shown. Emphatically, do not permit operators to pack the goods in tightly.

Sterilizer. In loading cylindrical sterilizers with loads of bulk goods, the operator should bear in mind that the perforated bottom tray plays an exceedingly important part. Air pockets gravitating down from the load are released to the space underneath the tray and are conducted freely to the chamber discharge outlet. If the tray is omitted or if it becomes flattened so that it conforms to the shape of the sterilizer, the back end of the chamber will become thoroughly air clogged. Sterilization will be very seriously retarded anu in addition the goods resting on the bottom will become saturated with water. Examine the tray frequently and make sure that it does lift the load free from the bottom of the chamber. In drum sterilization it is usually necessary to remove the bottom tray in order to get the drums in the chamber. This is permissible because the overhang of the drum cover will lift the drum sufficiently above the bottom to provide adequate discharge space.

Drum Sterilization. Sterilization in drums presents an unusual problem. Regardless of the number and arrangement of portholes in the drum, passageways for the escape of air and the intake of steam are restricted far more than when goods are put up in packs and for this reason loading of the drum is most important.

The tendency is always to overload the drum and without exception this is hazardous. Under no condition should the supplies be compressed into a tight mass nor should the drum ever be loaded to capacity so any slight pressure is required to close the cover. On the contrary, there should be some free space in the top of the drum when the cover is closed. Goods should be placed in the drum lying flat down so when the drum is placed in the sterilizer on edge the load also will rest on edge to promote steam circulation.

The type of drum must be considered also Older drums were made with relatively few port holes around the sides and these were usually concentrated near the center line in order to facilitate the use of sliding bands, the idea being that closure of the ports after sterilization would render the drum essentially dust proof. This idea has long since been found impractical, for the loose fitting cover will always admit air and dust quite freely. It is just as necessary to line any drum with double thickness muslin as to wrap loose packs with muslin. This covering of muslin surrounding the drum load serves as an air filter to eliminate dust as air is drawn in when the drum is removed from the sterilizer, as it surely will be when the drum cools. Sliding bands serve no useful purpose whatever, are something of a hazard because there is always danger that the drum may be placed in the sterilizer with the ports closed.

FIG. 45. Arrangement of goods within the drum is most important. The double thickness muslin liner must be ample in size to provide for thorough covering and securing of the top when the load is in and it should be so arranged that it can be used to drape the sides of the drum, presenting only sterile surfaces, when the muslin liner is opened. Under no condition should canvas liners be permitted because they will surely interfere with steam penetration. Muslin bags made to fit the interior of the drum are sometimes used but they seem to serve no valuable purpose. We believe the plain wrapper is preferable. Note that all articles are folded flat, not rolled, and there is and must be no suggestion of crowding.

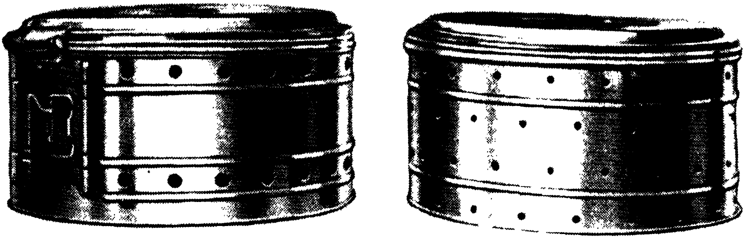


FIG. 46. Modern drums have no sliding bands with which to close and open ports around the side walls. Instead, there are more and better distributed ports. Sliding bands serve no useful purpose whatever and are sometimes hazardous as when operators forget to open the ports during sterilization. The drum at the left has a sliding band. The right hand drum has no sliding band.

Modern drums have no sliding bands but do have more and much better distributed port holes all around the side walls for the free escape of air and the entrance of steam. In some respects such drums can be recommended. Provided only that rigid standards for loading are maintained they can be used to advantage, especially when very large sterilizers are used. It is not difficult to specify exactly what materials shall be packed in each drum and with this established system, the drums can be stacked in the sterilizer (always on edge obviously) with no danger of overloading the sterilizer. Again, it will not matter whether the sterilizer contains one or twenty of these standardized drums—the period of sterilization, after the thermometer indicates the required range, will be exactly the same.

Sterilization in Enamelware Jars or Cans. Here we have still another problem which must not be considered in the same category with drum sterilization. The covers of such jars must be loose-fitting, never a tight closure and the jars must be placed in the sterilizer on their sides. The covers can be secured loosely in place with cotton tape tied on or they can be removed to bring about sterilization. Removing the covers is not good practice however, because there is an obvious break in technique in exposing the contents temporarily while the operator replaces the cover in removing the jars from the sterilizer.

At the best this method of containing supplies is open to some objections. There are no ports around the sides for the escape of air and intake of steam. Instead, all air escape and steam intake must occur through the open end. If the jar is placed in the sterilizer upright, with or without the loose cover in place, all air in the jar is perfectly trapped within. It simply cannot escape and the only sterilizing influence will be an indeterminate mixture of steam and air contacting the goods. Placed on its side in the sterilizer, there

will be a slow discharge of air from the open end by gravity and a corresponding slow intake of steam, provided the jar is only very loosely filled with light substances such as gauze or cotton pledgets. Such jars should never be filled to capacity, should never contain anything more dense than cotton or gauze, for steam penetration at the best is very slow.

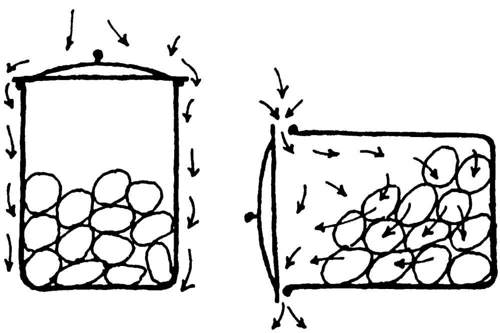


FIG. 47. Showing the correct and the incorrect way to place jars of dressings or cotton pledgets in the sterilizer. With the jar right side up, even if the cover is left off, all air is trapped in the jar by gravity. It cannot escape and steam cannot get in except in a very doubtful mixture. Sterilization will be questionable. Holding the cover on loosely with a band of cotton tape and placing the jar in the sterilizer on its side, as shown at the right, will permit air to flow out in the presence of steam just as water would. Steam will take its place and complete sterilization can occur. Under no condition, however, should jars of this general type be filled to capacity, nor should tightly compressed materials of any kind be sterilized in jars. They are suitable only for very loose dressings—gauze or cotton pledgets. Tightly filled, there is a tendency for air clogging of the materials in the bottom of the jar.

This analysis of jar sterilization which results from many potentiometer tests furnishes the background for a most significant rule which governs sterilization of many similar articles, such for example, as delicate instruments in test tubes. If the tube or jar is closed, no steam can enter at all and the only sterilizing effect must be limited to the dry heat developed from the surrounding steam, far below that range necessary for destroying even the least resistant of the pathogenic organisms. Here is the rule which should be memorized by every worker having to do with sterilization:

> *In sterilizing any dry material contained in a test tube or jar, imagine that the container is filled with water. Place it in the sterilizer so all the water would drain out. Air will act in the same way in the presence of steam because it is much heavier and if the air gravitates out of the container, steam will take its place. If this flow of air from the container is restricted, the intake of steam will be similarly restricted.*

Use Double Thickness Muslin Covers for all Package Goods. Rather exhaustive tests were made some years ago by one of the large University Hospitals to determine the efficiency of double

thickness muslin covers in protecting sterile supplies from contamination in routine handling. It was found that packs protected in this way remained sterile on the supply shelves for considerably more than two weeks, sufficiently protective so that two weeks was fixed as the period of time (maximum) storage would be permitted before re-sterilization. In making this statement it is assumed of course, that the muslin is in good condition, not worn thin. The purpose of the muslin is not only to protect the contents from contact contamination but also to act as an air filter to remove dust from air drawn in as the pack cools down after sterilization. The practice of using two thicknesses of muslin is almost universal and seems to require no particular discussion. The writer has seen worn out muslin used for the purpose, a practice which obviously is dangerous. If the muslin is worn thin or has holes in it, it can have very little protective value.

Do Not Use Canvas for Pack Covers or for Lining Drums. Canvas is used for sails and for tents and awnings because it is very tightly woven. When moistened as in the presence of steam, the pores close up still more tightly. Used for covering sterile packs or for lining drums, it most seriously interferes with steam penetration and should never be used. Similarly canvas is occasionally used for table drapes and it constitutes something of a hazard, particularly when wrapped up with other articles in the same pack. If any article of the kind is made from canvas, it should always be wrapped by itself, but preferably canvas should not be used at all.

Paper Wrappers and Paper Bags. Even heavy wrapping paper offers very little resistance to the passage of steam and if the paper is handled carefully so it is not ruptured, it furnishes very good protection of sterilized articles. Paper bags can be used to advantage

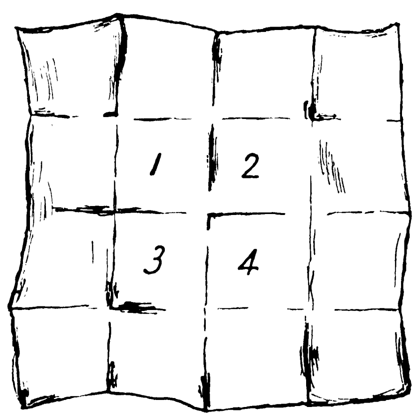


FIG. 48. Large rubberized sheets constitute one of the most difficult problems encountered in the surgery for sterilization. The fabric is not porous, steam cannot penetrate it and when the sheets are folded in order to get them in the usual sterilizer, some of the inner surfaces will be air clogged so completely that no direct steam contact is possible. The areas 1, 2, 3 and 4 shown in the sketch, on both sides, will be well isolated from steam contact.

for certain floor supplies such as gauze sponges, cotton pledgets and the like. The only fault to be found in the use of paper for surgical supplies is that sterilization usually renders the paper somewhat brittle and rupture of course, makes the wrapping useless. In at least one very large hospital, paper wrapping has been used extensively for surgical gloves.

Rubber Table Covers or Drapes. These are probably the most difficult articles found in the surgery to sterilize. The material may be pure gum rubber or rubberized fabric. In either case the material is not porous, steam will not penetrate it. If sterilization occurs, steam must contact all surfaces in which case the problem is very simple, but that is a real problem because the large sheets must be folded in order to get them in the sterilizer. A single rubberized sheet perhaps four feet square, if folded into flat sections to permit its entrance to the average sterilizer, would if opened up, present fold areas like 1, 2, 3 and 4 in Fig. 48. These areas would be completely enclosed or air pocketed and sterilization would be most questionable.

That such sheets must be used in surgery for any critical purpose is to be regretted. It is difficult to wash sheets of large size with the care, for example, with which rubber gloves are washed. The writer once saw a rubber sheet, part of a brain set, being folded on the floor of the work room because there was no table large enough to accommodate it. This is extremely poor technique because the floor of any room would be the source normally of the worst sort of contamination. Resistant spores have their origin in foul places, decaying animal or vegetable matter, and such organisms might easily be tracked into the work room from the street.

It is difficult to formulate any system of handling such sheets which will bear analysis. Perhaps the most practical method is to fold them once on the narrow dimension, with the surfaces inside the fold well separated from each other by a muslin covered cotton pad about half an inch thick. Then insert the folded sheet in a double thickness muslin bag formed for the purpose and large enough to contain the full length of the sheet. Roll this package very loosely and place it in the sterilizer preferably by itself but certainly never crowded in tightly with other packs. The outer surfaces will receive the full effect of the steam but the inner folds will be less readily contacted.

Preparation of Rubber Gloves for Sterilization. In order to completely sterilize rubber gloves, all surfaces must be contacted by the steam of the sterilizer. Heat conducted through the walls of the glove, without the moisture factor, is inadequate to destroy even the less resistant pathogenic organisms. A test was conducted to

prove this point. One of the less resistant organisms was planted in the finger of a glove which was then collapsed by folding so steam could not enter the finger. Sterilization for thirty minutes in a well regulated sterilizer failed to destroy the organism, but the glove was ruined by the long exposure. The usual good grade of rubber will not withstand sterilization for more than 15 to 20 minutes without serious deterioration, nor will rubber stand up in steam temperature even for short periods of exposure much higher than 250° F. These are our very definite limitations. We must bring about sterilization in 15 to 20 minutes without exceeding about 250° F. This can be done if the gloves are prepared with care.

It is true enough that interior surfaces of gloves do not normally contact the open wound during surgery unless the glove is cut or is torn and the surgeon's hands are never completely sterile. Nevertheless, attempt should be made to approach the ideal in this respect and that calls for unusual procedures. We begin with the assumption that the glove has been most carefully washed before sterilization. That of course, cannot be considered as sterilization in any degree but it does facilitate the process to this extent, that the glove is not polluted with dangerous organisms as might be the case otherwise. To illustrate this point, the writer knows of a fairly busy small hospital where for several years all gloves were sterilized in a metal box by a formaldehyde process known later to be completely useless, yet there were no difficulties experienced that could be traced to the gloves. On the other hand, the gloves had been washed with meticulous care which undoubtedly accounted for the freedom from trouble. We by no means advocate washing as a sterilizing process but we do emphasize the point that careful washing does make sterilization of these difficult articles less a problem.

We recommend as excellent precautionary procedure, turning back the wrist of the glove over a thin pad of gauze which will hold the rubber surfaces apart to give access to steam. This is stressed particularly because those wrist surfaces when opened up are exposed to the open tissues more or less. We further recommend that a thick pad of cotton gauze or muslin be inserted in the glove hand as far as the fingers and about as wide as the hand opening of the glove will permit. This will hold the glove open for steam entrance as far as the fingers. No one has yet devised any practical method for holding the fingers open but they will remain reasonably open for the intake of steam unless they are collapsed in the sterilizer or in tight wrapping.

Tight wrapping must be avoided. Any two surfaces of the glove, in close contact with each other, will eliminate direct steam contact with those surfaces. Heat of the surrounding steam will be trans-

FIG. 49. Illustrating gloves prepared for sterilization, with a gauze pad in the space where the wrist is folded back. This keeps the rubber surfaces of the wrist separated so steam can contact them. Another gauze pad is inserted in the hand of the glove as far as the fingers. This permits steam to enter the glove and if the fingers are not collapsed by tight wrapping, steam can enter them also. The instrument tray makes an ideal container for wrapped gloves. They should not be crowded together any tighter than the picture indicates.

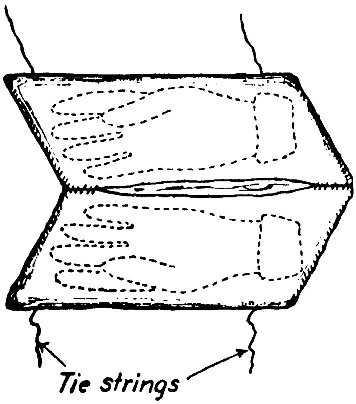


FIG. 50. A type of glove envelope in quite common use. It is made like a bill fold with a pocket for one glove on either side of the median line. Most envelopes are made too small so that some crowding results. The pocket should be about 11½″ long and 5″ wide. The opening to the pocket should be closed for 1½″ at each end to avoid contact contamination in handling. Use of tie strings avoids pins or paper clips for holding the envelope closed.

mitted through the rubber walls but no moisture will be present. This feature must be considered as the proper guide for wrapping, to so prepare the glove that no pressure is applied that might force any two surfaces of the glove, the glove fingers for example, into close contact with each other.

The cut Fig. 50 shows a type of glove envelope in very common use. If the envelope is sufficiently roomy it will perhaps serve the purpose as well as any other but some careful observers object to such envelopes from the angle of possible contamination in handling and prefer double thickness muslin wrappers completely enclosing the gloves.

Paper wrappers for gloves have not come into common use but one very large institution has used them for a considerable time with apparent success. A tough brown paper is used and it is previously formed or folded as a suitable container. In this case one of the newly developed glove dusting boxes (American Hospital Supply Corporation) is used. The box has a glass top, is electrically lighted and has a flexible front cover through which the operator's arms are inserted. Gloves are dusted and enclosed in the paper wrappers inside the box so that no dust escapes into the room.

Gloves should always be sterilized by themselves to avoid any crowding. It is imperative that the gloves be stacked very loosely. A large instrument tray makes an ideal container for them. Place the packs of gloves on edge, very loosely and never stack them more than one tier deep. Sterilize for 15, never more than 20 minutes at maximum temperature of 250–254° F.

Nail Brushes. First subject brushes to thorough washing. Use a perforated instrument tray for sterilizing. Place brushes in tray bottom side up, just one layer of brushes, nothing on top or compressing bristles. Cover entire tray with muslin. Sterilize 10 minutes (no more) at maximum temperature of 240–250° F.

Careless handling of brushes—compressing bristles by tight wrapping or meshing the bristles of two brushes together will result in quick destruction.

***Cellulose or Cotton Napkins.** Do not roll cotton or cellulose napkins or other cellulose products because this will cause distortion. Do not wrap them tightly and do not pack them in tight masses in the sterilizer.

Some brands of cellulose may turn creamy in color from the heat of the sterilizer, while others under similar sterilization will turn brown. Absorption capacity of cellulose increases 10 to 50% by steam sterilization, if properly dried out in the sterilizer. Some brands will shrink both in length and width during sterilization while other brands do not shrink appreciably.

*Johnson and Johnson

If conditions permit, it is desirable to sterilize cotton or cellulose napkins and other cellulose products by themselves in very loose arrangement. If this is done, the sterilizing period of exposure may safely be reduced to 20 minutes at maximum temperature of 250–254° F.

***Lamb's Wool.** This product can be sterilized by pressure steam but the wool will lose some of its resiliency and life from the heat of the sterilizer. Do not pack it in tightly with other supplies. Preferably sterilize it by itself at temperature never higher than 250–254° F. and the period of exposure can be reduced to 20 minutes.

***Adhesive Plaster.** It is not advisable to attempt to sterilize adhesive tape in the hospital. Manufacturers have developed special adhesive plaster and procedures for sterilization which are quite difficult but reliable and if sterile adhesive is required, it is best to secure it in sterile form.

***Catgut Sutures.** These are made from the sub-mucous layer of the small intestines of sheep and normally they are purchased by the institution only in sterilized tubes. Sterilization in the hospital is rarely if ever practiced because resistant spores are commonly encountered, buried in the gut. Sterilization as conducted by the reputable manufacturers is intricate but exacting and very dependable.

Boilable and non-boilable designation refers to whether exterior of tubes can be sterilized by heat or must be sterilized chemically.

Non-boilable sutures contain a small percentage of water in the tubing fluid which results in soft and pliable strands. If such tubes are subject to heat, hydrolysis of the catgut takes place, turning the collegen of the gut to gelatin. Therefore, suitable chemicals must be used to sterilize the exterior of such tubes. Before immersion in germicidal solution, tubes should be washed thoroughly in green soap or other good operating room soap, to cut any grease which might be on the exterior, preventing antiseptic solution from contacting the tubes. Such tubes should be completely immersed in germicidal solution for a minimum of 12 hours before use.

Boilable sutures are put up in anhydrous tubing fluid. The strands are stiff and wiry when removed because they are dehydrated. Boilable tubes should be sterilized in pressure steam.

***Silk Sutures.** Untreated silk sutures should be sterilized in pressure steam rather than by boiling. Routine sterilization for 30 minutes at maximum temperature of 250–254° F. is adequate. Repeated sterilization affects the strength very little.

If sutures are artificially waxed in the surgery, the wax definitely should be sterilized in the hot air oven for one hour at 320° F.

***Silkworm Gut.** This material, if autoclaved directly, is too stiff

*Johnson and Johnson

and brittle to use because insufficient moisture will be absorbed from the steam to soften the tough strands. While it has been common practice to boil silkworm gut for thirty minutes prior to use, this is not necessarily an adequate sterilizing procedure although it will properly soften the strand for use. It is suggested that silkworm gut be submerged in distilled water in a suitable vessel and thus autoclaved for thirty minutes at a maximum temperature of 250–254° F. The resultant strands will be found soft and pliable.

***Horsehair Sutures.** Horsehair is heavily contaminated with spores and the usual autoclaving procedure may be inadequate. These sutures should be secured from the manufacturer only in sterile form, the institution hardly being justified in attempting the special cleansing processes and sterilization methods required, particularly when considering the limited amount of such sutures normally used. A common method employed by the manufacturer is to cleanse the hair thoroughly and then apply dry heat sterilization in which the temperature is sufficiently great to destroy resistant spores.

Pressure Steam Sterilization of Instruments. This method of sterilizing surgical instruments is rapidly being adopted as standard in many institutions because of the speed and effectiveness of the performance primarily. In addition, pressure steam is less injurious to the instruments.

Routine sterilization of instruments by boiling normally requires 20 minutes exposure. In emergency, with expressed permission of the surgeon, exposure is reduced to 10 minutes—and far too frequently, exposure is limited to much less than 5 minutes. In boiling, the temperature never exceeds 212° F and the sterilizing effect is a product of this moderate temperature plus superabundance of moisture. The reduced periods of boiling in emergency will probably kill all vegetative organisms but are inadequate for destruction of spores.

Pressure steam sterilization, on the contrary, very quickly heats instruments to a (saturated-with-moisture) steam temperature of 250° F. and at this range and under this condition destruction of the resistant pathogenic spores occurs in one minute.

One point deserves special comment. Unlike any other load subjected to pressure steam sterilization, the instruments will receive the full benefit of the steam heat at the sterilizing range, actually before the thermometer can indicate that temperature, because there is nothing to permeate with steam, only surfaces to contact, and the steam must pass through and around the instruments before it reaches the thermometer bulb.

*Johnson and Johnson

To clearly define instrument sterilization in pressure steam, it is necessary to analyze those factors which may have some retarding effect. If instruments are thoroughly washed, if there are no minute crusts of pus or blood concealed in inaccessible joints or grooves, then surface sterilization is all that is required and two or three minutes exposure is adequate. This perfectly clean condition is not always assured. To break down (dissolve) these crusts concealed and possibly dried on in inaccessible places requires, not higher temperature as sometimes advocated, but additional time in which the moisture of the steam can soften and permeate them completely.

For routine sterilization it is excellent practice to establish 10 minutes as the exposure period with the sterilizer regulated to maintain maximum temperature of 250–254° F. Higher temperature is neither necessary nor desirable. Some authors have advocated much higher temperatures on the theory, apparently, that greater speed in sterilizing is thus made possible. We have, however, the authority of an article published in the official journal of the American Society of Bacteriologists in stating that the resistant pathogenic spores of which C. tetani, C. welchii and C. oedematiens are typical, are destroyed in direct contact with steam at 250° F. in one minute. In the light of this very dependable information, we are not justified in suggesting higher temperatures than 250–254° F. At this range of adjustment, the sterilizer is equally useful for sterilizing rubber drainage tubes, rubber gloves and other surgical supplies with no change whatever in regulation.

For emergency sterilization, the period of exposure can safely be reduced to 5 minutes, still providing a considerable margin of safety. With some reluctance we suggest that in extreme emergency, where seconds count, it is permissible to reduce the period of exposure to 3 minutes. There is no doubt at all that under normal conditions, this exposure will be found ample because, as suggested above, the instrument surfaces will be heated to the sterilizing range before the thermometer indicates the temperature, and throughout sterilization the instruments are drenched with water, the condensate from the steam. The only point open to question in reduced exposures is the possibility of hard, dried crusts of pus or blood concealed in joints or crevices which routine washing has not eliminated. These require time for dissolving which accounts for the routine 10 minute period of exposure recommended for normal requirements.

Pressure steam sterilization is much less damaging to all instruments than boiling because it permits no scale (lime) formation, impossible to avoid when instruments are boiled in tap water. No matter how carefully instruments are washed, if they have been routinely boiled for some time scale formation will be found, this is

frequently discovered when instruments which have been previously boiled for sterilization are subjected to steam sterilization. For the first few trips through the sterilizer, brown tarnish spots will be noticed on the surfaces which many observers believe to be rust. Sometimes pressure steam sterilization has been condemned for this reason. The brown spots are not rust, but scale from the instruments which the steam has loosened. After four or five trips through the pressure sterilizer, the tarnish spots will disappear and thereafter the instruments will come through bright and free from tarnish.

The best method we have seen for handling instruments in the pressure sterilizer is illustrated by Figs. 51 and 52. The procedure is as follows: Place a towel or muslin cover in the bottom of the tray. Place delicate instruments, scalpels, etc. in close contact with the porous fabric. Cover the delicate instruments with another towel or muslin cover for protection. Place the remainder of the load of instruments above and cover them preferably for protection in transit, as a precautionary measure particularly for the protection of the more delicate instruments. With this exception, there is

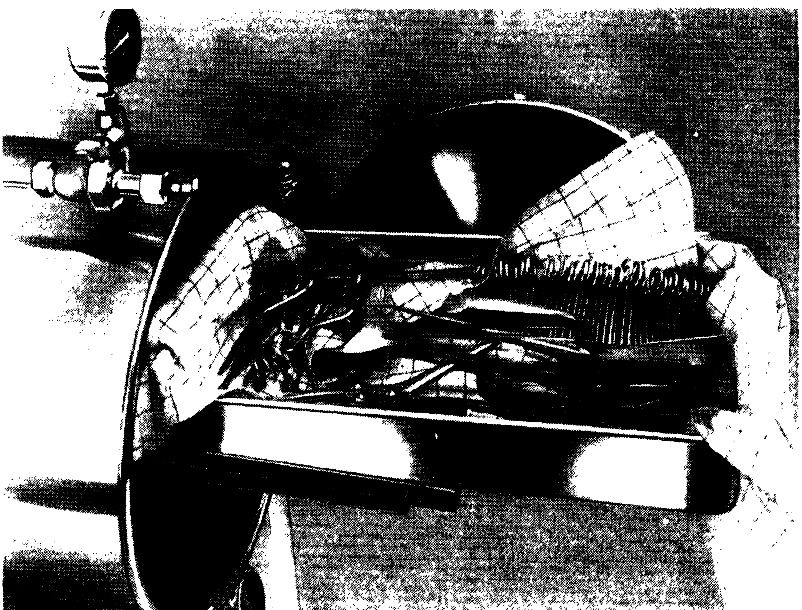


FIG. 51. A towel placed in the bottom of the tray protects delicate instruments such as scalpels from injury. Separate the layers of instruments in the tray with other layers of soft fabric and cover the top layer as a protective measure to prevent contamination in transit to the surgery.

no more need for the towel covering than when instruments are boiled.

While it is possible, is in fact quite common practice, to sterilize suture needles in the pressure steam sterilizer, it is much better to subject them to sterilization in the hot air sterilizer. At times, under the greatest of care, suture needles will tarnish when sterilized by any wet process and it is most difficult and time consuming to scour them clean again. In the hot air sterilizer they will not rust at all. See the chapter on "Hot Air Sterilization".

Spare scalpel blades are commonly sterilized chemically and preserved in sterile condition immersed in some antiseptic solution. This method is open to criticism as is all chemical sterilization—the hazard of not knowing the strength of the solution or allowing insufficient time. Pressure steam sterilization is infinitely better and quite simple. Place the individual blade in a small medicine bottle with only the tiniest wisp of cotton or gauze holding the blade from injurious contact with the glass walls. Stopper the open end of the bottle with cotton and wrap the bottle in muslin. Place the bottle in the sterilizer lying on its side, of course, to permit air to escape so

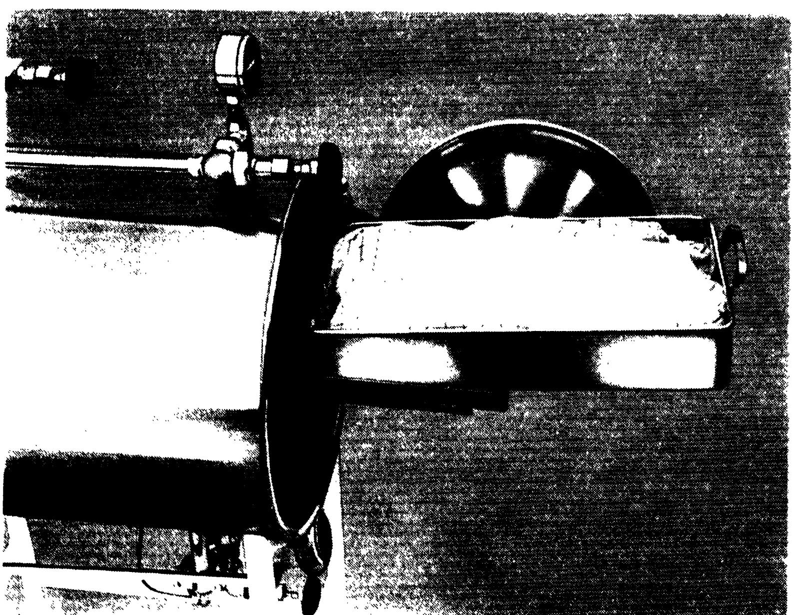


FIG. 52. Protection of the loaded tray with some soft fabric covering is desirable but no more necessary than similar protection for boiled instruments.

that steam can enter. Place the pack above heavier packs in the load and sterilize for 15 to 20 minutes at maximum temperature of 250–254° F. Fig. 53 illustrates the proposed method of preparation.

Operators are cautioned against the practice of attempting sterilization of any instrument in tightly stoppered bottles or test tubes. Do not use rubber caps or anything more restrictive than loose cotton or a muslin cap tied on, else air will be effectively trapped within and steam cannot enter. The container must be placed on its side also or the air will be trapped within.

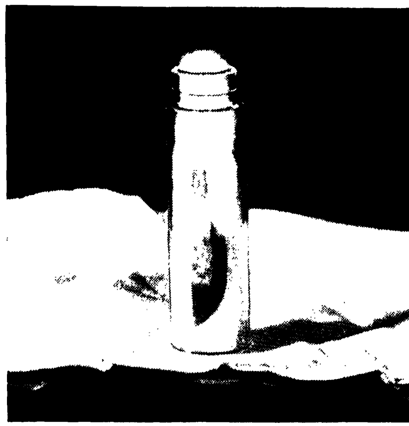


FIG. 53. Showing a scalpel blade in a small medicine bottle, arranged for pressure steam sterilization. Place the bottle (wrapped in muslin) on its side in the sterilizer and sterilize for 15 to 20 minutes at maximum temperature of 250-254° F. Thirty minutes exposure with bulk loads of dressings to the same temperature is also permissible.

Soiled instruments direct from the operating table can be washed and sterilized in the pressure steam sterilizer to excellent advantage, especially septic instruments. If special washing trays are not available for the purpose, use any porcelain or stainless steel or monel basin suitable in size that will fit in the sterilizer. Do not use aluminum—it will discolor. Open up jointed instruments in the tray, cover them with the hottest water available and add (preferably in solution) a tablespoonful of tri-sodium-phosphate or about the same amount of Calgonite or Soilax. Place the tray in the sterilizer by itself, of course, and subject it to routine sterilization for 15 to 20 minutes. Then at the close of the period of exposure, open up the exhaust and let the pressure escape just as rapidly as possible. Wait until chamber gauge has shown zero pressure for a few minutes before opening the door. The instruments will be found bright and clean and they will be unquestionably sterile.

Remove the tray from the sterilizer, pour off the water and while the instruments are still wet, wipe them off to remove any traces of shreds which may adhere to joints or rough edges. No further

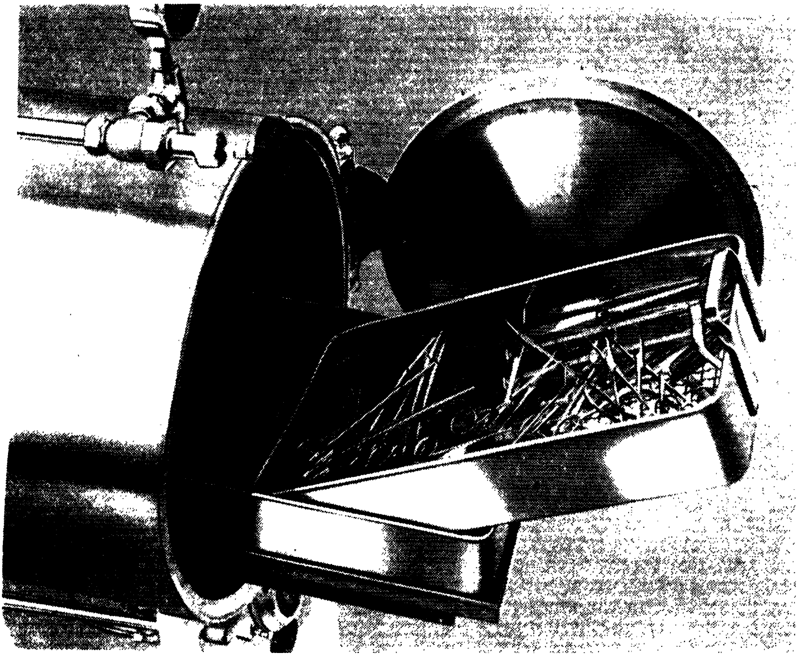


FIG. 54. Illustrating special tray equipment which is available for washing and sterilizing septic instruments. The outer tray contains the water while the inner tray has a wire mesh bottom which permits lifting the washed instruments from the water. A tray carrier can also be provided, adaptable to any modern pressure sterilizer, to facilitate handling the trays from the sterilizer.

cleansing is necessary. The instruments should be re-sterilized routinely before use.

Sterilizers specially adapted to instrument sterilizing and washing are now available with monel trays suited to the requirements. These are illustrated in Fig. 54. In addition, further developments in design have made it possible to eliminate the basin of water which must be emptied in removing washed instruments from the sterilizer, accomplishing the same results with much less effort. Such sterilizers are equally useful in routine sterilization or for washing and sterilizing instruments.

It is thoroughly practical to wrap instruments in double thickness muslin covers for sterilization in pressure steam, just the same as other surgical supplies. This practice is especially useful in preparing instruments for dressing trays or carts, but the practice can be carried still farther to advantage. In at least one very large hospital, trays of instruments in complete, organized sets are made up

and sterilized in the afternoon for the following day's work. The complete tray is wrapped in muslin and stored over night, ready for use. The only objection to this method is the usual lack of sufficient instruments to meet the requirements.

Instruments wrapped in muslin covers should be routinely sterilized for 15 to 20 minutes because there is some retardation in the penetration of steam through the covers.

Pressure Steam Sterilization of Utensils. Boiling of utensils for sterilization is no longer considered good practice in the surgery for various reasons, particularly because boiling always leaves a deposit of scale on the utensils which is most difficult to remove. Pressure steam sterilization eliminates the scale altogether, leaves the utensils bright and clean.

Wrap the utensils individually or nest them if that is more convenient, with a layer of muslin or a towel between utensils to separate them so that steam can enter freely. Protected with the usual double muslin cover they will remain sterile in storage the same as bulk goods. Preferably sterilize utensils by themselves for an exposure period of 15 to 20 minutes. Be sure they rest in the sterilizer on edge, in such position that if they contained water it would all drain out. So arranged the surfaces will all receive direct steam contact and sterilization will occur very quickly.

If utensils are sterilized with bulk supplies, they should of course, be wrapped separately and so arranged in the sterilizer that they do not interfere with direct circulation of steam to other supplies. Avoid placing utensils above other supplies, preferably stack them by themselves at one end of the sterilizer.

CHAPTER X

Methods of Testing the Performance of Pressure Steam Sterilizers

Unless the Sterilizer Is Temperature Controlled, Detectors Should Be Used with Every Load. Using any of the older forms of pressure controlled steam sterilizers, those in which the drainage discharge is controlled by hand regulation or those which are controlled automatically in this respect, but without temperature measurement of the results, there is constant and very grave need for a dependable type of sterilization detector such as the Diack Control, for everyday use. Such a control, if properly used, will indicate to the operator and to the supervisor, whether or not adequate temperature has been developed during the period of exposure. Lacking some dependable check of this kind, sterilization may become distinctly hazardous before the faulty performance is discovered and corrected.

With any of these older forms of sterilizers so much is dependent upon the individual who operates the sterilizer that, lacking any other means for indicating or recording temperature, there is no safe substitute for the sterilization detector. These serve, if properly used, to guard against the use of surgical supplies which have not been properly sterilized.

The following example will illustrate the purpose served by a dependable detector. A survey was made of a group of sterilizers in a prominent hospital where serious infections had caused a temporary closing down of one of the departments of the surgery. All of the sterilizers in the hospital were being operated at from 17 to 22 pounds pressure. None of these sterilizers were temperature controlled. In each case partial air evacuation was secured by an initial 10″ vacuum. In no case was any serious attention given to the additional discharge of air through the chamber drainage system. No type of sterilization detector was being used.

In one test, pressure was held at 18 pounds for 30 minutes. The highest temperature developed in a moderately packed drum of general supplies was 151 degrees F., a lag of 105 degrees behind that indicated for pure steam at the pressure carried. Of course sterilization was incomplete.

In another department, a similar drum of supplies was held at 20 pounds for 30 minutes, developing a temperature in the load of

174 degrees F. at the close of the period, a lag of [illegible]5 degrees behind that indicated for pure steam by the pressure gauge the only indicator the operator had of sterilizing influence.

In neither case was anything wrong with the sterilizer. Both of these drums were later sterilized in the same machines at the same pressures, but with proper regard for control with the chamber drain valves, in 30 minute periods developing respectively 256 and 259 degrees F. considerably before the close of the periods of exposure.

In another test in this hospital, the period of exposure was continued for a full hour at slightly higher than 20 pounds pressure. The highest temperature developed was 220 degrees, a lag of about 40 degrees behind that indicated by the pressure gauge. This latter test indicates that sometimes even a prolonged period of exposure at abnormally high pressure does not necessarily insure sterilization.

It is most significant that this hospital had a short time before, discontinued the use of Diack Controls in an attempt to economize. If temperature controlled sterilizers had been used, or if dependable detectors had been properly used, every one of these faulty performances would have been unmistakably indicated before the materials were admitted to the surgery.

It should be thoroughly understood that the essential purpose of any detector of sterilization is to indicate to the operator and to the supervisor, whether or not the performance has been faulty. Inadequate air elimination is almost invariably the cause of all sterilization failures. This always means that inadequate temperatures are developed particularly in the lower area of the load.

Properly Applied and Used, The Recording Thermometer Is a Most Practical Detector of Faulty Sterilization Performances. In making this statement, it is assumed that the hospital has carefully established definite standards with respect to the size and character of every pack and for loading the sterilizer. This, in our opinion, is a fundamental necessity without which sterilization can become hazardous. If various individuals or departments in the hospital are permitted to prepare materials for sterilization without rather rigid supervision of standards with respect to quantities and arrangement it will be impossible or impractical to set up standards at all and the use then routinely of detectors such as Diack Controls will be almost imperative.

Assuming that definite standards have been set up and are maintained, the sterilizer of the modern temperature controlled type will reproduce exactly the same sterilizing influence on the load every time it is used. The recording thermometer will furnish an unmistakable record of each performance and variation in these records from day to day should not, need not, be permitted. The operator

sees the record as it is traced on the chart. Timing is definite. If any material variation in these chart records does occur, the supervisor can immediately detect it and correct the fault. Without the recording chart, the operator can show no proof of what she may have done with the machine and the supervisor has nothing with which to check the work of her subordinates.

It is obvious that if certain standards are set up and proved to be effective, that reproducing and recording a given performance that conforms with those standards represents a close approach to the ideal. For this reason we stress on every possible occasion the need for Centralized Sterilization in which definite standards can be established and maintained.

Diack Controls. The control consists of a light brown tablet of a chemical substance contained in a small hermetically sealed glass tube. Its indication of sterilization, unlike some other controls offered, is positive. Under sterilization conditions, the tablet in the glass tube will melt, fuse, change its shape. Usually the tablet will change in color to a bright carmine but this is not the distinctive change. The operator should be guided only by the melted or fused condition.

We have for years consistently advocated the use of Diack Controls when the use of any control is indicated or desired, our reason being that after testing many hundreds of them under widely varying conditions of application, we have yet to find one which does not conform to the general characteristics claimed for them.

If the control is buried in a pack of goods, in the most-inaccessible-to-steam-contact location in the pack, as it must be to serve a useful purpose, and if the control is fused after sterilization, that indicates that the entire pack has been subjected to steam at a temperature and for a period of time necessary to bring about sterilization. Our tests show uniformly that under this condition of testing, the control will fuse in 5 to 8 minutes at temperatures of 248-252° F. At slightly lower temperature the time required to fuse the control increases rather rapidly. For example, at 245° F. twenty to thirty minutes will be necessary. At materially higher temperatures than 250° F., the time required for fusing will decrease rapidly.

A good deal of confusion has occurred in testing these controls sometimes by attempt to fuse them in an open flame or other direct contact with relatively intense heat. That is not the way the control functions in any sterilizer. Permeation of any pack of bulk goods with steam and corresponding heat occurs relatively slowly and as the goods are heated, the control also is heated, gradually attaining the temperature at which fusing occurs.

Maximum, Self-Registering Thermometers. Such thermometers

are used infrequently for checking sterilization. They indicate only the highest temperature to which they have been subjected. They do not indicate the time factor. Good thermometers of this type are fairly expensive and are easily broken. Unless the thermometer is known to be accurate, particularly within the sterilizing range (240 to 250 degrees F.) it should not be used at all. If accurate, it can be used to denote steam penetration very effectively and is desirable for occasional checks for steam penetration through dense, heavy packs of supplies.

Lag Type Thermometers. This type of maximum, self-registering thermometer includes a time lag factor, supposedly of 10 or 15 minutes. In other words, when the thermometer shows upon removal from the sterilizer a temperature of 250 degrees, that is supposed to indicate that that temperature has been maintained for the lag period. Actually this lag factor is uncertain. These thermometers are expensive and easily broken, and rather bulky so much so that it is difficult to use them properly within the hearts of packs and to arrange for removal without disturbing the wrappers or contaminating the packs. The Diack Control is considered to be a more practical method of detecting sterilization.

Culture Tests. The great difficulty with the use of any culture test is that so much time must elapse after the test has been made before the results are known. In this interval, while the culture is being incubated and examined, the materials, perhaps unsterile, will be needed for use.

The commonly used culture test also is not properly indicative of sterilization because nearly always some vegetative type of microorganism is used for the test one which is easily destroyed at temperatures far below the normal temperature which should be developed by the machine for the destruction of resistant spores. Any test to be indicative of correct sterilization procedure, should be far more exacting. Too much reliance is placed on such tests.

It is suggested that cultures for such tests should be prepared, using some dry spore form such as B. subtilis—not moist cultures in the vegetative stage in which they are easily destroyed. B. subtilis is suggested because it is not dangerous—not pathogenic, and because it has the approximate characteristics of the dangerous and resistant pathogenic spores with respect to its resistance to destruction by steam.

How Every Sterilization Detector Test Should Be Made. It has been previously explained that the coolest part of any sterilizing chamber is to be found at the bottom, because if any air remains in the sterilizer it will gravitate to lower areas. For this reason, the detector of whatever form it may be, should be placed in the center

of the largest and most densely wrapped package in the load, and this package should rest on the tray in the bottom of the chamber.

If the detector is placed in the sterilizer carelessly, without regard to this detail, it may be dangerously misleading, should the sterilizer be performing badly. It is not uncommon to find the temperature in the top part of a badly air clogged sterilizer 50 degrees higher than in the bottom of the load. A properly evacuated chamber will have very uniform temperature throughout.

Diack Controls and other detectors are often placed outside drums at the extreme top of the chamber, or tied to the end frames of loading carriages, or perhaps located just under the covers of packages. Tests made under such careless conditions mean nothing, and may develop a false sense of security in a highly inefficient machine.

It is more difficult to place detectors in drums than in loose packs, but by no means impossible. There is just one correct way. Locate the detector in the exact center of the load within the drum. Conduct the thread attached to the detector out through the folded top of the double thickness muslin cover, with which the drum is lined, and leave some of the thread exposed outside the cover. After sterilization, open the metal drum cover and pull out the detector for observation.

Do Not Depend on Any Pressure Gauge as Indicative of Sterilization. The indication of pressure as previously explained, is almost meaningless in conducting sterilization processes. Pressure of itself has no sterilizing influence. The indication of sterilization must, in some manner, measure the true sterilizing influence—temperature. Pressure gauges must be used on all sterilizers of this general type, however, as a matter of regulation of pressure for the attainment of temperatures which should be otherwise measured.

Do not use any pressure gauge unless the indicator hand returns to zero or very close to zero, when the sterilizer is cold. If the gauge has been distorted so that the hand shows pressure of perhaps several pounds when the sterilizer is idle, call a competent mechanic to reset the hand, or to renew the gauge.

The commercial gauges commonly used on sterilizers are never very reliable, even when adjusted so the hand returns to zero when the sterilizer is idle. The so-called commercial tolerance at the sterilizing range of 15 to 20 pounds pressure, is between one and two pounds. In other words, the reading of the gauge at these pressures may vary one or two pounds on either side of the indicated pressure. For this reason, when very careful tests are to be made, gauge the performance by some type of instrument of known accuracy.

Use Only Mercury Type Thermometers for Critical Measurement of Temperature. Accurately calibrated mercury thermometers

are not subject to fatigue changes—they remain reliable indefinitely unless the mercury separates or the bulb is broken, both of which faults are easily detected. It is possible to secure mercury thermometers that are reliable and accurate at the sterilizing range, within one degree. This should be one of the fundamental sterilizer specifications—that the thermometer used shall be of the mercury type—guaranteed to be accurate within one degree between 240 and 250 degrees F. Commercial thermometers of any type are subject to sometimes radical inaccuracies unless the specification of accuracy at the critical range is guaranteed.

Good clinical thermometers, it will be recalled, are always of the mercury type because of the need for permanent, dependable accuracy.

Vapor-tension type thermometers, such as those commonly used on automobiles and for other approximate temperature indications, are not permanently reliable. They can quite easily get radically out of adjustment. Even though means may be provided for readjustment, they are not practical for such uses, because operators cannot recalibrate them and cannot detect erratic performance.

Pressure recording thermometers are of this general type, but being of expensive tailor-made construction, are less open to criticism than the usual indicating instrument. Even the recorders require frequent checking for which reason they should be used on sterilizers also equipped with indicating mercury thermometers. The pen arm on the recorder has a micrometer adjustment screw and since the arm is extremely light and flexible, it frequently becomes distorted a bit. To check its accuracy, run the sterilizer until the maximum temperature becomes stable, then adjust the pen arm until the recorder indicates the same temperature as the mercury instrument.

How Diack Controls Can Be Used for Setting Up Standards for Sterilizing Systematically Prepared Loads. Assemble a typical heavy load of supplies, as heavy and dense as any that will be permitted. Then select half a dozen of the heaviest and most densely wrapped packs or drums. Place one Diack Control in the heart of each of these packs, then place the packs on edge in the bottom of the sterilizer.

Put in the remainder of the load as it will normally be placed. Now sterilize the load for a 30 minute exposure, timing the period when the thermometer indicates 240° F. and with the sterilizer regulated to produce a maximum of 250–254° F. Now examine the controls at once. If any single control remains unfused, examine first the make up of that pack to see if it can be reduced in size or arrangement to permit more rapid permeation with steam. Also look

for unusually dense materials such as canvas table or instrument drapes. If there is nothing abnormal about the pack, examine the way it has been placed in the sterilizer. Perhaps too heavy packs have been placed above it, interfering with the passage of steam to it.

Usually if the packs under test are uniform in size and contents, failure to fuse one or two of the controls will mean that the load above the packs is too heavy or it may mean that all the packs are a bit too heavy or dense and need to be reduced in size somewhat so that there will be a greater margin of safety.

If the packs cannot be reduced in size, if the arrangement is in accord with the methods recommended in chapter IX, then repeat the test with the same packs after they have been thoroughly dried out and cooled. This time increase the period of exposure by 5 minutes and check the results. If this test fails, even in one pack, make a more rigid inspection of the wrapping and arrangement of the load. It is inexpedient to sterilize longer than 30 to 35 minutes and usually it will be found practical to further reduce the size of packs.

In any event, continue tests of the kind until an exposure period has been determined in this way adequate for fusing all the controls. Once having established a standard of the kind, it is obviously necessary to maintain it both with reference to wrapping and loading and to sterilization.

Check the Load Before it is Removed from the Sterilizer. In one of the largest of our University Hospitals, an orderly runs the sterilizers but every load is checked by the supervisor of Central Supply or her assistant, before the load is removed. In this case, a recording thermometer tells the story in which the checker is interested. No variations are permitted and once the practice has been established, operators are keen to observe the exact routine demanded.

If the sterilizers are operated by more than one person or if student nurses are employed for the work, it is excellent practice to require double checking. The load is examined by an inspector before the door is closed and the period of exposure is checked by the inspector before the door is opened. Rigid inspection is most desirable in maintaining high standards.

Chapter XI

Preparation and Sterilization of Aqueous Solutions, Distillation of Water

Preparation and Sterilization of Rubber Tubing and Glassware

Preparation and Sterilization of Aqueous Solutions. Sterilization of fluids in flasks involves a different use of steam than is required for dry goods sterilization. In the latter case we are concerned with permeation of steam through the mass of goods in order that both heat and moisture shall be absorbed by the fibers. In solution sterilization, the moisture factor is present in the fluid, and we are required only to apply heat. The steam from which heat will be condensed on the walls of the flasks and the condensate will drain to the bottom of the sterilizer and be discharged through the chamber drain. This process will continue until the fluid has been heated to the temperature desired. The time required for this heating process governs the period of exposure and will vary with the size and shape of the container, the amount of fluid and the thickness of the container walls. These determinations have been made for various sizes of flasks and bottles and will be quoted later in the text.

In operating the sterilizer, regulation of pressure and temperature and definition of period of exposure are the same as for dry goods, but since both factors are of extreme importance, we shall repeat the rules again briefly.

Regulation of the Sterilizer means adjustment of automatic pressure control to maintain sufficient pressure to secure maximum temperature indicated by the thermometer of 250°-254° F.

Period of Exposure Is Defined as beginning when the thermometer indicates 240° F. and continuing thereafter for the prescribed period, during which the thermometer indication will gradually advance to a maximum of 250°–254° F.

The Cycle of Performance in solution sterilization is very interesting. During all the period while the solution is being heated and as long as period of exposure continues, there is no ebullition of the fluid (visible indication of boiling), though the fluid temperature will advance to 240°–250° F., far above the boiling point of water at

atmospheric pressure. This is due to the steam pressure maintained in the chamber, at all times equal to or in excess of the pressure possible to develop from the heat in the fluid. Until this condition reverses there can be no ebullition, but exactly that does occur in the process of cooling. When the chamber pressure is permitted to reduce, the pressure corresponding to the temperature of the fluid will be greater than the steam pressure and the fluid will begin to boil. If chamber pressure is exhausted rapidly, ebullition will be so violent that stoppers may be blown out and some of the fluid will spill out into the sterilizer.

With a specially constructed sterilizer we have been able to observe this reaction and to formulate a satisfactory method of cooling. This sterilizer has an observation window in the side and the interior of the chamber is electrically lighted so that the flask can be seen all through the performance. In this manner it has been found that when chamber pressure is exhausted at a uniform rate during a period of not less than six or seven minutes, the fluid temperature can keep step closely with that of the surrounding steam and the rate of boiling will be so slow that no fluid will be lost except through vaporization.

But when cooling is accomplished with the greatest of care, there is always some loss of fluid by vaporization, about 3% to 5%. This establishes a general rule for making up solutions which should be observed. Add an extra 5% of distilled water to each flask so that the sterilized product will have closely the concentration intended.

On the other hand, too slow cooling may affect the period of exposure very seriously. If the period is over extended, the effect is the same as over exposure. If the heat is turned off the sterilizer at the close of exposure and the machine allowed to cool down without opening the exhaust, a period of about half an hour will elapse before the pressure reaches zero. During all this period, the fluid will be maintained between the maximum temperature of 240°–250° F. and 212° F. For many solutions such as saline this prolonged exposure will do no harm whatever, but any heat-sensitive fluid such as glucose will be injured, and the fault will be indicated by some slight degree of color change. Fig. 55 illustrates this feature.

Determination of Period of Exposure For Solutions. Because flasks of solution are of fixed capacity and because it is impossible to crowd them together into a tight mass, retarding sterilization, it is safely possible, and in many cases necessary, to restrict the period of exposure to a degree that will provide only a small safety factor as compared with those set up for dry goods in which the heat capacity of loads may vary widely. Any flask of solution will receive a definite sterilizing influence under any given performance of the

machine and that influence will be duplicated exactly every time the sterilizer is used, provided the sterilizer is operated uniformly.

Again, the minimum requirements as set up governing sterilization of dry goods are abnormally high when applied to aqueous solutions, because the fluid contains that extremely important moisture factor in abundance. The resistant organisms are more easily destroyed when heated in water than as encountered in dry packs. These and associated factors have been considered carefully in the establishment of various periods of exposu quoted herein.

Operators must remember that the size and type of flask used, not the number of flasks in the sterilizer, establishes the period of exposure. If the flasks are all alike, period of exposure will be just the same for one or any number of flasks. The period of time required to bring temperature (thermometer reading) to the sterilizing range of 240° F. will vary with the size of the load but exposure period should not vary.

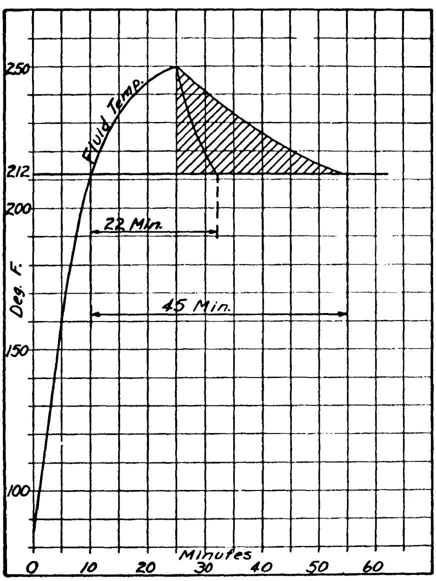


FIG. 55. Showing the overheating effect of abnormally prolonged cooling, resulting from permitting the sterilizer to cool down without exhausting steam from the chamber. With exhaust properly regulated, chamber steam can be discharged and fluid temperature reduced to 212° F. in 6 to 10 minutes, a total period in this case as shown of 22 minutes during which the fluid has been at or above 212° F. But when the sterilizer is allowed to cool down without exhaust of chamber steam, this period is prolonged to 45 minutes, definitely harmful to any heat-sensitive fluid.

Suppose that a load is presented for sterilization comprising ten 1000 cc. flasks of saline and ten 2-ounce bottles of procaine. If all these flasks and bottles are placed in the sterilizer at once, the period of exposure will need to be 15 minutes for the larger flask and in this time the procaine will be oversterilized and this will be indicated by some color change, very slight perhaps, but sufficient to render the fluid more or less unfit for use. Loads of this kind should be broken up into flasks or bottles of the same size and sterilized separately.

Following is a table of exposure periods which have been established by carefully conducted potentiometer tests of which Figs. 56 to 62 are typical:

2000 cc. Florence flask (thin glass)	15–20 minutes' exposure
1800 cc. Fenwal flask (thick glass)	25–30 minutes' exposure
1000 cc. Florence flask (thin glass)	13–18 minutes' exposure
900 cc. Fenwal flask (thick glass)	19–24 minutes' exposure
500 cc. Florence flask (thin glass)	10–15 minutes' exposure
250 cc. Florence flask (thin glass)	8–10 minutes' exposure
125 cc. Florence flask (thin glass)	8–10 minutes' exposure
50 cc. Florence flask (thin glass)	6–8 minutes' exposure
2-ounce commercial bottle (thick glass)	8–10 minutes' exposure
1-gallon commercial jug (thick glass)	35–40 minutes' exposure

Minimum periods of exposure as given above represent, in our opinion, the least periods under which sterilization should be attempted and the maximum periods quoted should not normally be exceeded. For routine, it is advisable to use the average of the two figures in setting up standards. In this respect a recording thermometer is of inestimable value. The operator may forget to time the exposure properly but reference to the chart on the recorder indicates at a glance exactly when temperature did reach 240° F. and similarly exactly when the exposure is complete. The supervisor should routinely check the charts and in this way be enabled to correct any inconsistencies.

This table of exposure periods covers the flasks in most common use but attention is drawn to our ability and willingness to test other types and sizes of flasks and to present data corresponding to test charts (Figs. 56 to 62). To secure such data, forward samples of the bottles or flasks in question to Department of Research, American Sterilizer Company, Erie, Pennsylvania. There will be no charge for such institutional service.

In Figs. 60 and 61 we have shown a direct comparison between thin glass flasks and Fenwal standard flasks. This is in no sense to be construed as criticism of the Fenwal flask but denotes merely the greater resistance to heat penetration of the heavier glass. The Fenwal flask is necessarily heavier to resist the collapsing strain resulting from sealing under vacuum.

Do Not Overfill Flasks. From the foregoing explanation it will be evident that flasks should not be filled to capacity. This holds true for any container of fluids subjected to sterilization that is not hermetically sealed (before sterilization), as with some commercially prepared fluids. It is better to fill the flask not more than three-quarters or two-thirds full. If the flask is filled to the top, the slightest ebullition will cause some of the fluid to overflow.

The charts shown on this page show the results of potentiometer tests of various Florence (thin glass) flask. Fenwal (thick glass) flasks and thick glass bottles. In each test the curve indicates fluid temperature. The timing line is indicated at the left of each chart, as the time when the thermometer indicated 240° F. The sterilizer was regulated to produce a maximum temperature, shown by the thermometer, of 252° F. The initial fluid temperature was in each case 70° F.

Do Not Use Rubber Caps or Any Tight Fitting, Non-Porous Stoppers. In the process of sterilizing, temperature will be developed in the fluid corresponding to 10 to 15 pounds pressure. If the flask

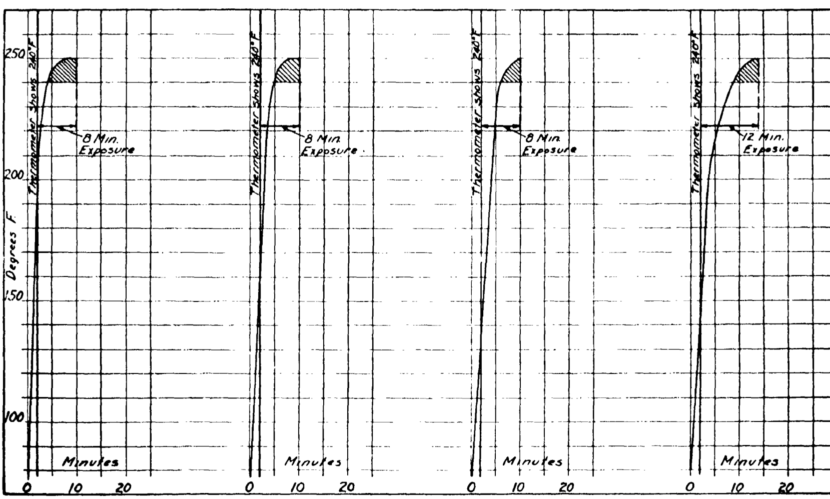


FIG. 56. 2 ounce commercial thick glass bottle containing one ounce of water. Exposure 8–10 minutes.

FIG. 57. 125 cc. Florence thin glass flask containing 100 cc. of water. Exposure 8–10 minutes.

FIG. 58. 250 cc. Florence thin glass flask containing 200 cc. of water. Exposure 8–10 minutes.

FIG. 59. 500 cc. Florence thin glass flask containing 400 cc. of water. Exposure 10–15 minutes.

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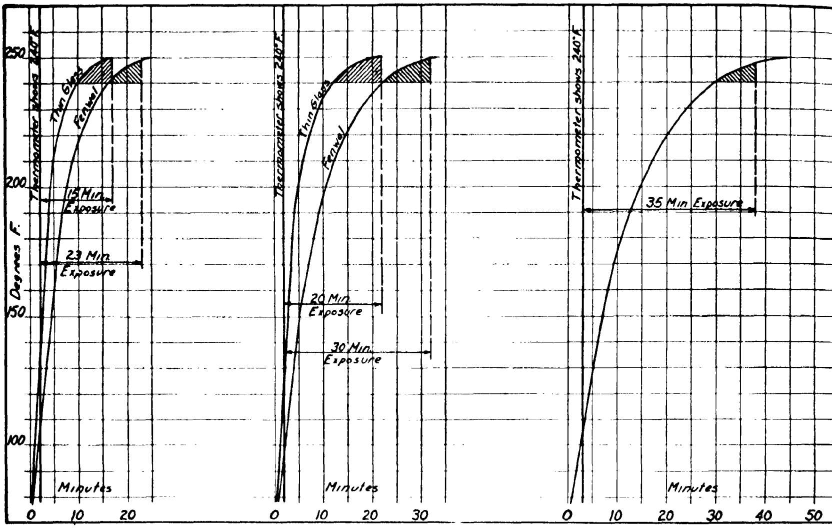

FIG. 60. Comparison Fenwal 900 cc. thick glass flask and 1000 cc. Florence thin glass flasks, each containing 900 cc. of water. Exposure (Fenwal flask) 19-24 minutes. Exposure (Florence flask) 13-18 minutes.

FIG. 61. Comparison Fenwal 1800 cc. thick glass flask and 2000 cc. Florence thin glass flasks, each containing 1800 cc. of water. Exposure (Fenwal flask) 25-30 minutes. Exposure (Florence flask) 15-20 minutes.

FIG. 62. One gallon thick glass commercial jug filled to the dome with water. Exposure 35-40 minutes.

is stoppered tightly and the stopper held in so that it cannot blow out, the fluid temperature will surely develop pressure within the flask which may be dangerous. Ordinary glass will not withstand these pressures, or if the glass is unusually strong, sudden chilling from a draft of air may cause explosion. Similarly, when rubber caps are used, they will sometimes be blown off. If they are a bit loose fitting, they will open up enough to exhaust the pressure in the initial cooling, then when the fluid cools to room temperature, the top of the cap may be drawn in under vacuum. There is no assurance, however, that they will seal under vacuum and if they do not seal tightly, no filtration of intaken air will occur.

The Breathing Effect of Fluids In Cooling. When a flask of fluid is removed from the sterilizer, its temperature will normally be about 212° F., the boiling point of water at atmospheric pressure. Then as the fluid cools to room temperature, there will be a definite intake of air, referred to as "breathing." Unless adequate protection is provided for filtering this intaken air, the fluid will be contaminated. This indicates the need for an air filtering cover, but to emphasize

the point we shall quote an interesting test. A vacuum gauge was attached to the side outlet of a flask containing water at the boiling point. The top outlet of the flask was tightly stoppered. In cooling to room temperature, vacuum of 26″ was indicated on the gauge, nearly perfect vacuum.

Tough, Smooth-Surfaced Paper Caps Are Recommended. Machine formed caps are now available in various sizes to fit commonly used flasks, in which the skirts are uniformly fluted to simplify application as shown in Fig. 63. These are easy to apply, but a certain protective routine should be observed. Bind any such cap in place at two locations on the neck, the first just under the rim of the

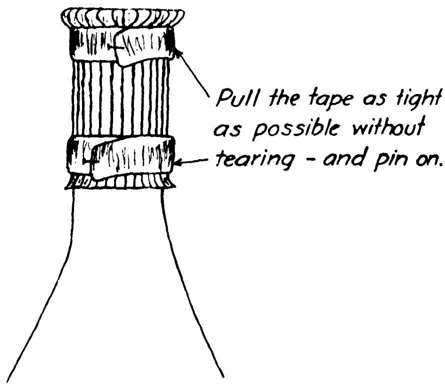

FIG. 63. Method recommended for binding paper caps to flasks. Use cotton tape and pull it up tight around the neck of the flask, just under the rim of the flask and again at the bottom of the skirt. Pinning the tape in position, without puncturing the paper, insures a tighter closure than is possible by tying.

flask, the other close to the bottom of the skirt. Use cotton tape and draw it up as tightly as possible without rupturing the paper and preferably pin the tape in place. Tight binding is emphasized to insure that any air drawn into the flask must pass through the paper, not through loosely held flutes. These formed paper caps can be secured from Frank M. Sayford Co., 50 Washington Street, Brooklyn, New York.

Lacking formed paper caps, it is possible to improvise a suitable paper covering. Use three thicknesses of thin, tough, smooth-surfaced paper. Form the paper around the neck of the flask as smoothly as possible, with uniform flutes. Bind the cover in place as explained in Fig. 63.

Do Not Use Cotton Plugs or Stoppers for Parenteral Fluids. It is not good practice to use any form of cotton as a covering for flasks because of the danger from lint or dust. In the process of cooling, some moisture will always be absorbed by the stopper and as it ultimately drains back into the flask, any free lint or dust may be carried with it to the fluid.

Use Cellophane Only As a Mechanical Protector for Another Stopper. Neither steam nor air will pass through cellophane, so it is useless as a filtering medium. If a covering of cellophane is bound securely and steam tight to the neck of a flask, it will surely be ruptured by pressure generated during initial cooling. It is sometimes used as a mechanical protector for paper caps. Bound on securely over the paper, intake air will pass very slowly through the paper surrounding the neck of the flask.

Examine Flasks for Ruptured Stoppers After Sterilization. Using any form of porous stopper, there is always some danger that the covering may be ruptured by too rapid exhaust of steam from the sterilizer. If this occurs, the flasks are unfit for use because the openings in the stoppers where ruptured permit intake of unfiltered air.

Avoid Careless Handling of Sterilized Flasks. If a sterilized flask is turned on its side or otherwise mishandled so that fluid wets the stopper, the fluid may soak through and become contaminated.

Do Not Store Parenteral Fluids In Heated Cabinets. The newer technique in this respect calls for administration of fluid at room temperature. In Jefferson Hospital, Philadelphia, where the detail has been given studious attention, it is a fixed rule that there shall be no reheating of parenteral fluids after sterilization. Storage of such fluids in heated cabinets is considered hazardous because prolonged heating, even at moderate temperature, may be injurious to heat-sensitive fluids.

The Fenwal Flask (Hermetically Sealed After Sterilization). This very special flask and dispensing equipment has gained rapidly in popularity in recent years. Its value seems to have been well substantiated by satisfactory service in numerous exacting institutions. It furnishes a degree of protection of fluids after sterilization, impossible to attain with any porous type of stopper. Flasks and dispensing equipment can be secured from Macalaster Bicknell Co., 171 Washington Street, Cambridge, Massachusetts.

The flasks are available in various sizes, of Pyrex glass in modified Florence pattern. The peculiar value of the flask is associated with the system employed for hermetic sealing which comprises a heavy rubber cap with a central outlet fitted with a stainless steel secondary stopper. During sterilization the secondary stopper is inserted only part way, leaving a breathing hole through which pressure otherwise developed in the flask during initial cooling can be exhausted. When the flask is removed from the sterilizer, the operator pushes the secondary stopper all the way in, closing the flask hermetically. The metal stopper has a large umbrella-like top which protects the top of the flask and serves as a handle for removing the

stopper. As the flask cools to room temperature considerable vacuum is formed and if this vacuum is not broken to let in air, the fluid will keep indefinitely.

Before use each flask is subjected to a sudden jar and if a water hammer noise results, that indicates the flask is vacuum sealed and fit for use. A dead sound indicates the vacuum has been broken and the flask is discarded. In dispensing, the secondary stopper is removed and the special dispensing tube inserted in the opening. Means are provided for suspending the flask inverted.

Distilled Water for Parenteral Fluids

The Water Still Must Be Kept Clean. This point has been recognized by authorities for years, but too frequently stills are put into service and operated for long periods of time with no cleaning of the interior parts until something goes drastically wrong. Practice has clearly indicated that the product from a single distillate still of good general design is perfectly suitable for parenteral fluids when, but only when, the still is clean. Conversely, the product from a still of the most elaborate design will be unfit for use when the apparatus becomes foul. Periodic cleaning should constitute a fundamental law in the operation of any still. The frequency of cleaning will depend upon the purity of the raw water supply.

When parenteral fluids first came into extensive use, serious difficulties were experienced with distillate taken from inefficient or foul stills, and in the effort to solve the problem, double and triple stills were widely advocated, users forgetting that while double or triple distillation might postpone the day, that ultimately these stills would also become foul and their product unfit for use. Cleaning double or triple stills involves twice or three times the labor, expense and delay needed for cleaning a single still.

This is a perfectly correct presentation of facts as they have been developed in practice and in selecting a still for parenteral fluids, this point should be given serious thought. Any still in continuous, day after day service, will become increasingly foul until, regardless of all the protective baffles and intricate passageways with mysterious names, the product becomes unfit for use. Ultra refinements in the performance of a clean still are not significant but the intent should be to provide an apparatus instead which will produce initially water of satisfactory purity, with the all-important provision of means for maintaining that quality by daily cleansing.

The still Fig. 64 has been designed specifically for production of distillate for parenteral fluids. Repeated tests in various laboratories have shown the product to be sterile, pyrogen free, containing total solids of less than two parts per million. Interior parts of the

still are perfectly accessible for inspection or cleaning, without the use of any tool. The evaporating pan, held by the operator, is attached to the body of the still, or detached, by a twisting motion which actuates a bayonet joint. This pan should be removed daily for thorough rinsing, to remove the floating mud and scale, solids removed from the raw water. This simple daily cleaning will keep the still operating at top efficiency with respect to water quality. Hard scale adhering to the coil will slow down the performance, cause the still to produce less than its rated capacity, but it does not affect the water quality. When the coil becomes badly coated, it can be removed by disconnecting unions and a clean (spare) coil put in its place in a few minutes. The coated coil can then be treated

FIG. 64. Simplicity in cleaning is an all important factor with any still. The cut shows a type of still in which the evaporating pan, in which the solids from raw water are accumulated, is removable without tools for daily cleansing.

with acid to remove the scale and retained as a spare, so that no delay occurs when this cleaning becomes necessary.

One of the factors essential to good still operation is "maintenance of uniform water pressure." If the water pressure varies considerably, it is impossible to maintain uniform performance. If the still is steam heated, as most production stills are, it is equally necessary to maintain uniform steam pressure on the supply lines. Wide fluctuation of water and steam pressures can usually be cared for perfectly by installing suitable water and steam pressure control valves which can be regulated at a somewhat lower average range.

Testing the Still for Water Quality. The most reliable and positive means for maintenance of uniform quality of distillate is provided in the use of a recording conductivity meter shown in Fig. 65. The instrument is expensive and comparatively few of them are in use for that reason, but it seems to be the one known method for proving day by day that the water quality is maintained at proper purity. It measures and records the electrical resistance of the water as it comes from the still. For safe use the resistance should not be less than 10,000 ohms. The pair of single stills (shown in Fig. 65) during a three day test in dust contaminated surroundings recorded resistance continuously of 20,000 to 25,000 ohms. To indicate its extreme sensitiveness, water in the condenser was contaminated with a single drop of dilute acid and again with a small pinch of (alkaline) soap powder. In each case the indicator instantly moved to the extreme low limit on the scale until the still could clean itself, discharge the impurities.

Use Only Freshly Distilled Water. This requirement is generally understood but it deserves emphasis. Water used for parenteral fluids must be fresh because distillate picks up contamination from the air at a very rapid rate. This means that distillate should be collected from the still and used at once.

Do Not Store Distillate for Parenteral Fluids in Metal Containers. Pyrex glass is recommended because this hard glass is not affected, as other forms of glass are, by distillate. Pyrex bottles and flasks are available in a variety of sizes suitable for thorough cleaning with acid, rinsing with distillate and sterilization if need be. Metal containers are not so easily cleaned and it is most difficult to protect fluids contained in them from contamination. Loose fitting covers are likely to become foul and it is questionable whether means provided for sterilizing the tanks, if any, are made consisteht use of. Also, tinning on brass or copper tanks may come off in spots, leaving raw brass or copper exposed to the action of the distillate.

Protection from Air Contact. It is always desirable to protect distillate and solutions in all stages of preparation, as much as is

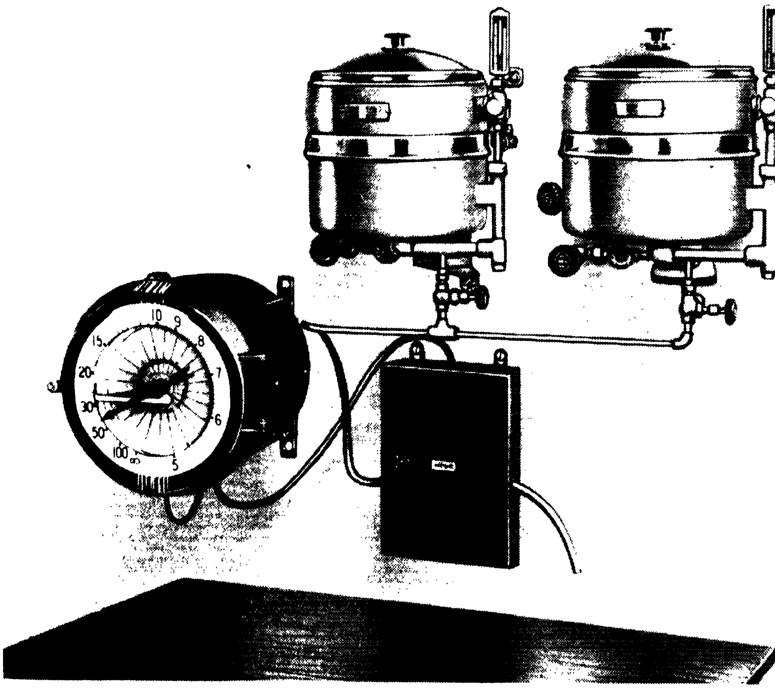

FIG. 65. Showing a pair of 5-gallon per hour single distillate stills equipped with a recording conductivity meter. Water from the stills is conducted to a glass U-tube in the closed box. Leads from the meter attach to the U-tube and resistance of the water as it discharges from the stills is measured and recorded on the meter chart. This system guards effectively against the use of contaminated water.

practically possible, from air contact. To this end it is recommended that when solutions are siphoned from one container to another, the air intake or vent tube in the container from which liquid is siphoned should be equipped with an air filter. Some air contact is of course unavoidable, as in filtering, for which reason the work should all be done at some location peculiarly free from dust.

Preparation of New Glassware. Wash thoroughly with soap and hot water, then rinse twice with very hot tap water. Soak one to six hours with cleaning fluid, then rinse six times with hot tap water, then rinse twice thoroughly with freshly distilled water and drain. Dry mouth down, do not wipe with a cloth.

Formula for Cleaning Fluid (Dichromic Acid).

Dichromate of potash	1 part
Sulphuric acid	1 part
Distilled water	10 parts

Dissolve the dichromate of potash in distilled water with heat, in a 6 litre Erlenmeyer flask. Cool. Cautiously add the sulphuric acid to the solution. CAUTION—always pour the acid into the solution, never the reverse. The solution can be used over and over until it becomes green which indicates the chromic acid has been converted into chromate.

Preparation of Used Glassware (Solution Flasks). Rinse three times with tap water, then rinse with cleaning fluid (dichromic acid), then rinse six times with tap water. Finally rinse twice thoroughly with freshly distilled water. Drain mouth down. If not for immediate use, cap with paper in storage.

Flasks known to have been used with drugs (Lugol's solution for example) should be treated as new flasks.

Preparation of New Rubber Tubing. It is extremely important to secure rubber tubing made from pure gum rubber of the highest possible standard. Ordinary tubing contains so much sulphur that special and rather difficult treatment is necessary to make the tubing fit for use in intravenous work. In one institution where very high standards prevail, all new tubing is routinely treated by circulating hot sodium hydroxide solution through and around the tubing for half an hour, to remove the sulphur. A surprising amount accumulates in the solution from this treatment which leads us to believe that more rigid standards are needed.

A less drastic procedure seems to suffice when great care is exercised in securing pure gum rubber tubing. We quote the practice of one of our largest hospital centers in this respect:

> Wash the new tubing thoroughly with soap and water and rinse well. Then boil in 5% solution of sodium bicarbonate for one hour. During this boiling process circulate the hot fluid through the tubing with a syringe. This should be done several times.
>
> Then wash the outside of the tubing thoroughly in hot tap water, then attach to a faucet connection and run tap water through the tubing for 3 hours.
>
> Now boil the tubing in tap water for one hour then run tap water again through the tubing for 30 minutes.
>
> Finally attach a funnel to one end of the tubing and run not less than one litre of freshly distilled water through the tubing. Drain and sterilize.

Preparation of Used Rubber Tubing. For tubing that has been used only for routine intravenous therapy the following process seems to meet the requirements:

Wash thoroughly in plain tap water, then attach to a faucet connection and run tap water through for 30 minutes. Then attach a funnel to one end and run through at least one litre of freshly distilled water. Drain and sterilize.

If it is known or suspected that used tubing may have been used with any drug, prepare the tubing the same as for new tubing.

Sterilization of Rubber Tubing. The sterilizing effect produced in the average performance for rubber tubing is theoretically open to serious criticism. From a practical standpoint it is probable that the very thorough washing and rinsing that normally precedes sterilization, especially the final rinse with freshly distilled water, accounts for the apparent freedom from difficulty in this respect. The point is that unless very special preparation of the tubing for sterilization is carried through, steam will never circulate through the tubing and the only sterilizing effect must result from dry heat conducted through the walls of the tubing plus whatever moisture there may be adhering to the interior walls of the tubing. Coupled with the fact that sterilization must be limited to a relatively short period of exposure to avoid destruction of the rubber, the assumption that there is sufficient moisture inside the tubing to bring about sterilization will not satisfy the more critical observers.

It is possible to assure steam circulation through the tubing but the process involves considerable detail and unusual care in prepara-

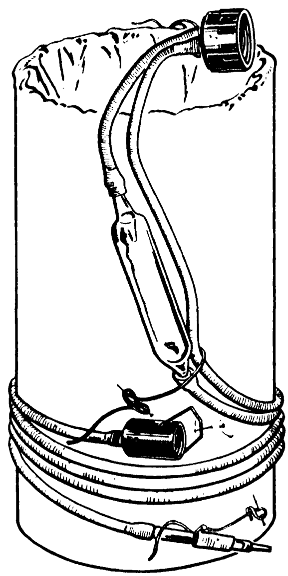

FIG. 66. This diagram illustrates what is intended by "spiraling the rubber tubing around a cylinder." In this position, if the tubing contained water, it would all flow out promptly. Similarly, in the presence of steam, air contained in the tubing would flow out so steam could take its place.

tion. The usual length of tubing will be approximately 30″ to 36″ and it will be completely filled with air at the start. The interior walls may or may not be moist but we have no means for accurately determining this point. If the tubing can be so placed in the sterilizer, with one end elevated continuously throughout its length above the other end, so that if the tubing contained water it would all drain out, then in the presence of steam, air would also drain out and steam would take its place very rapidly. This condition can be brought about by spiraling the tubing about a cylinder as indicated diagrammatically in Fig. 66. There must be no restriction of the tubing of course, that might interfere with free drainage. Fig. 67 shows a practical application of the principle as carried out in a large University Center. In this case the cylinder takes the form of a couple of hand towels around which the tubing is carefully spiraled. By placing the tray on its side in the sterilizer, circulation of steam through the tubing is provided for to the best possible advantage.

Usually it is most difficult to separate loads of bulk supplies so that trays of various supplies containing rubber tubing can be sterilized by themselves. This is a desirable thing to do because prolonged exposure is injurious to even the better grades of tubing. If the trays are prepared and wrapped as shown in Fig. 67, the period of exposure can safely be reduced to 15 minutes. If the trays

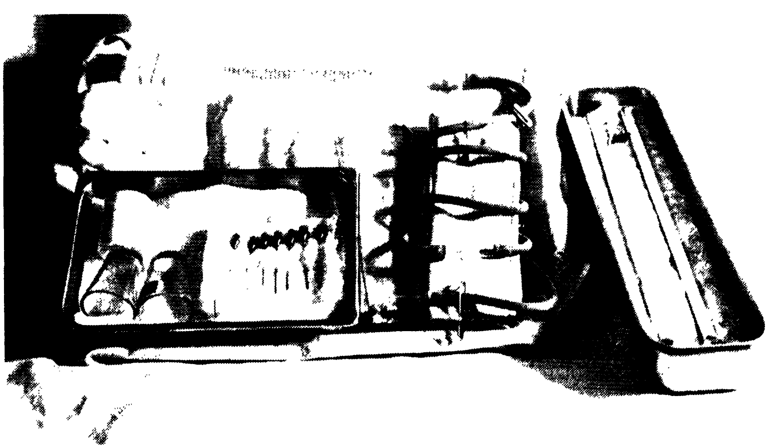

FIG. 67. Practical application of the tubing spiraled around a cylinder made from a couple of hand towels folded together. Air contained in the glass cylinder and in the tubing will flow out and steam will immediately flow in, to sterilize the inside of the glass and tubing, if the tray rests on its side in the sterilizer. Similarly the spinal manometer in the tray at the right is sterilized, with the tray having one end elevated considerably above the other or preferably resting vertically.

must be sterilized with routine bulk loads, then the period of exposure must be about 30 minutes and that practice is quite common. But in any event, great care must be exercised to place the trays very loosely in the sterilizer, resting always on their sides to permit steam circulation.

The all too common practice of placing trays of any kind of surgical supplies in the sterilizer right side up emphatically should not be permitted. Unless the tray is placed on its side in the sterilizer, all air is perfectly trapped in the tray and the only sterilizing effect must come from an indeterminate mixture of air and steam.

Chapter XII

Hot Air Sterilization

As an introduction to this subject, it is appropriate to explain somewhat in detail why certain products cannot be sterilized properly in the routine pressure steam sterilizer. Steam sterilization as normally employed is a product of heat plus moisture in which the moisture factor plays an exceedingly important part. Unless the product undergoing sterilization is such that steam can permeate the entire mass thoroughly, making direct contact with every fibre or particle, sterilization will definitely be incomplete, must be considered a hazardous procedure. The heat alone, without the moisture, developed in any normal pressure steam sterilizer will be insufficient.

Materials such as wax, various oils, vaseline in any form, bulk talcum powder, ointments, cannot be properly sterilized in the autoclave no matter how efficient the machine may be, because the moisture of the steam cannot be made to permeate such masses. Organisms buried or concealed in such products will be heated to the temperature of the steam, but lacking the moisture factor, those temperatures will be inadequate.

In presenting this statement to various of the average hospital personnel, the immediate reaction is very often this: "We have been sterilizing these products in the pressure sterilizer routinely for years and have had no trouble." That reply sounds conclusive but it is our firm belief that while infections of the kind are not commonly recognized—are not traced to their source, that they do occur but are so thoroughly obscured that routine investigation has not uncovered them. Too frequently infections of an unusual nature are charged against faulty sutures, careless technique or something else indefinite. It is difficult to trace such infections because they will be almost invariably delayed considerably, sometimes for days or weeks before the body tissues can absorb the wax or oil or vaseline, releasing the sealed-in organisms.

As typical examples, two infections in brain surgery were reported to us for investigation, the owners believing that the steam sterilizers were faulty. In one case the infection was observed three weeks after the operation and in the other case there was a delay of two weeks. Both were due to vegetative organisms, not spores. Investigation disclosed that pressure steam sterilized bone wax had been used in both cases, a process that had been routine in the

hospital for years and never before questioned. Lacking any better name for it this sort of thing has been termed "delayed infection," on the erroneous assumption that due to some unexplained peculiar condition of the organism it has failed to grow in the normal period. It is highly probable that such organisms are perfectly normal but have been unable to reach the tissues until the sealing-in oil or wax or vaseline has been absorbed.

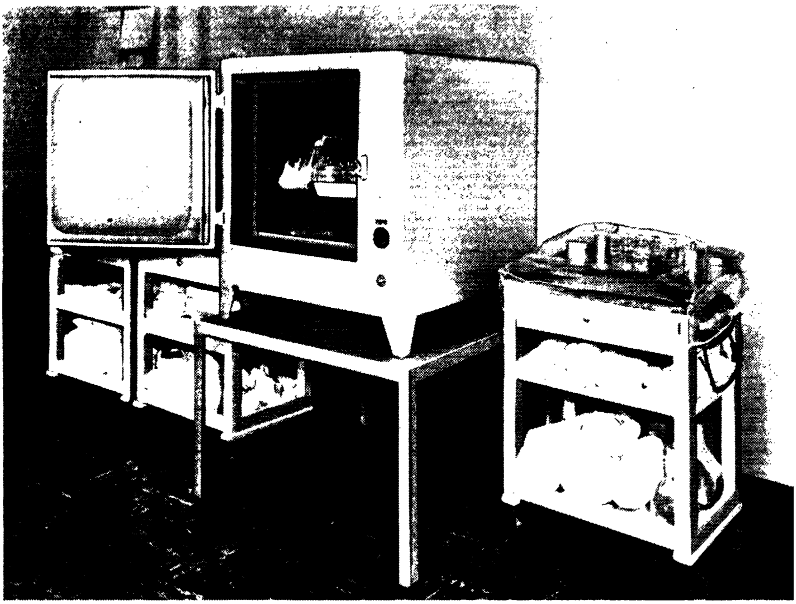

FIG. 68. Typical installation of the Hot Air Sterilizer in the central supply Department of St. Luke's Hospital, Cleveland.

We hear occasionally of other so-called "delayed infections" which sound suspiciously like sealed-in organisms released after considerable delay. For example, we have learned of one not very common practice of artificially waxing silk sutures in the surgery. If wax used for such purposes has not been hot air sterilized, the process is certainly open to criticism.

There are extensive records, incidentally, which indicate that silk sutures containing only the natural wax of the silk can be sterilized satisfactorily by routine pressure steam sterilization. But if the silk suture has been artificially waxed by the manufacturer, or elsewhere, but not sterilized, pressure steam should not be used. Instead, sterilize such sutures in mineral oil in the hot air oven at

320° F. for one hour, previously heating the oil before putting in the sutures.

The reputable manufacturers of sutures offer practically every form of suture in sterilized tubes. They have vast experience and research back of their carefully prescribed performances and it is doubtful if the average hospital can routinely equal the reliability of such sutures.

In attempting to explain apparent freedom from difficulties experienced when incomplete sterilization of these products has been followed, one must bear in mind that most of them—oils, vaseline wax—are probably delivered by the manufacturer in reasonably sterile condition and that they do not readily promote the growth of pathogenic organisms. These facts, coupled with partial (but incomplete) sterilization in the autoclave, account for this apparent freedom from trouble that has given rise to a false sense of security. We stress again the point that difficulties are probably experienced from incomplete sterilization of these products but have not been recognized because of the delay that may be expected before the organisms can grow.

Electric Heat Is Recommended for the Hot Air Sterilizer. We greatly prefer the electrically heated oven because of facility for accurate and reliable temperature control within the desired range. For most routine performances this temperature range should be close to 320° F. but the automatic regulator should be readily adjustable for lower temperatures as in the case of zinc peroxide for example. Gas heated ovens are commonly used in the laboratory for sterilization of glassware and other articles where an excess of heat is not objectionable. Gas cannot be controlled with the same accuracy as electricity and use of gas involves a considerable fire hazard.

Timing the Period of Exposure. The ordinary procedure is to place the load in the oven, close the door (and leave it closed) and turn on the heat. Time the exposure period only when the thermometer indicates the desired range. Do not open the door during exposure because the oven will cool quickly if the door is open. In sterilizing silk sutures in oil, first heat the oil to about the sterilizing range before inserting the sutures. This is done to prevent injury to the silk from too long exposure.

Talcum Powder. Put up in bulk in any type of container, circulation of steam in the pressure sterilizer is impossible and steam sterilization should never be permitted. Even in the hot air oven, because heat is transmitted through the air-filled powder so slowly, exposure should be not less than two hours at 320° F. Containers for talcum in bulk should never be large because of this slow heating factor.

Loose talcum on gloves or contained in small paper or muslin envelopes will sterilize perfectly in the pressure steam sterilizer because steam can permeate and contact every particle. Place the envelope within the outer glove cover but not inside the glove or the wrist fold of the glove for that would interfere with steam contact.

Various Oils. These should be put up in small bottles or flasks never filled to more than two thirds capacity to avoid spillage in the oven. The quantity of oil should be limited to that needed for any single application. Sterilize for one hour at 320° F. Large amounts of oil should not be sterilized in one container because an excessive period of time will be required to heat the mass to the desired range.

Bone Wax. Most of the bone wax available in this country is put up in small tubes which have been heat sterilized by the manufacturer. Exteriors of such tubes can be sterilized in the autoclave. Since the tubes are relatively small and inexpensive, the institution is hardly justified in buying unsterile wax or in attempting to sterilize partly used tubes. If unsterile wax is purchased, it should be put up in very small containers and sterilized for one hour in the hot air oven at 320° F.

Vaselinized Gauze. These strips of gauze imbedded in vaseline are often put up in fairly large trays containing a considerable mass of vaseline. The volume must be controlled in order to be sure of sterilization. We shall quote the experience of one large University Center where careful potentiometer tests were made to set up the standard: "Quart ice cream boxes with hinges added are used for containers. The volume of vaseline is limited to 4 ounces and the amount of gauze is limited to that which this amount of vaseline (vaseline cerate or xeroform ointment 3%) will impregnate. This container is sterilized for two hours at 320° F."

Iodoform Drainage Material. This material is available in sterile form from the manufacturers and unless the demand is quite heavy, it is advisable to purchase the sterile product. Since iodoform will not withstand sterilization, it is necessary to prepare this drainage material under aseptic technique. Sterilize the glycerine in the hot air oven at 320°F. for one hour. Use steam sterilized gauze, utensils, water. The operator prepares for the work the same as for surgery, scrubbed, with sterile gown, gloves and table drapes. Make a paste from iodoform powder and glycerine, add 95% alcohol until the paste is dissolved and the solution is a uniform yellow. Wet gauze in sterile water and wring as dry as possible. Dip gauze in iodoform solution until it is saturated, then squeeze out excess moisture but do not wring dry. Place in sterile containers and seal with adhesive until used. This is the process followed at Jefferson Hospital, Philadelphia.

Glycerine. Put up in small containers only and sterilize for one hour at 320° F.

Hypodermic Needles. While these can be sterilized satisfactorily in the autoclave and are so sterilized routinely, it is much better practice to sterilize them in the hot air oven because all moisture is eliminated and there is no question about sterilization of the bore of the needle. Place the needle with stylet in the bore in a suitably small test tube having a restriction in the barrel that will hold the needle point from striking the bottom of the tube. Special test tubes are now available having such restriction or ordinary test tubes can be flattened in a flame to serve the purpose. Use a tight fitting cotton stopper to close the open end of the tube. Sterilize for one hour at 320° F.

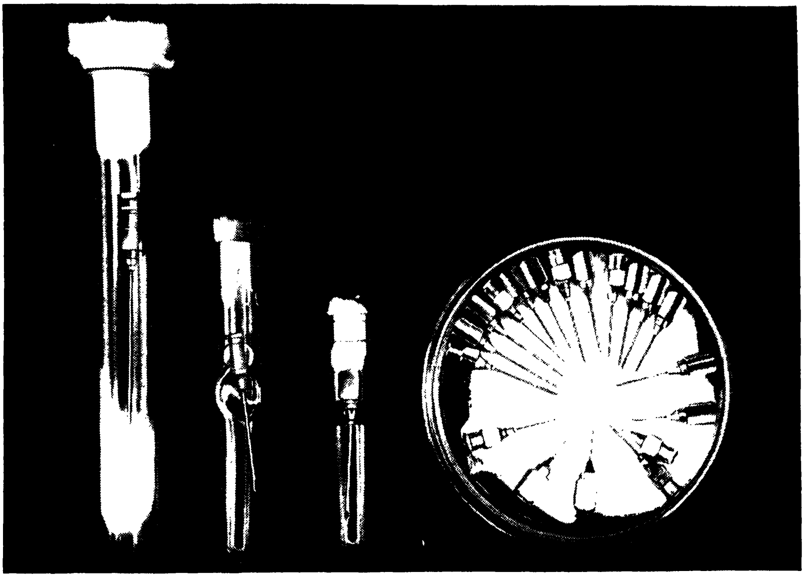

Fig. 69. Methods of preparing hypodermic needles for sterilization. The tube at the left shows a large needle with its point protected by cotton. This is not so good as use of test tubes with restrictions to hold the needle. The two center tubes have restricted sides. The one at the left has been flattened in a bunsen flame while the one at the right is a manufactured product. For clinical purposes the petri dish is quite satisfactory, containing as many needles as will be required, with points buried in gauze. All of these are sterilized in the hot air oven at 320 F. for one hour. The same tubes can be used also for pressure steam sterilization, care being taken to place the tubes on their sides so that air can escape and steam can enter. Do not attempt to sterilize petri dishes filled with needles in the autoclave. There is no way to eliminate the air. Stylet should be removed for steam sterilization of any needle, or steam cannot enter the bore.

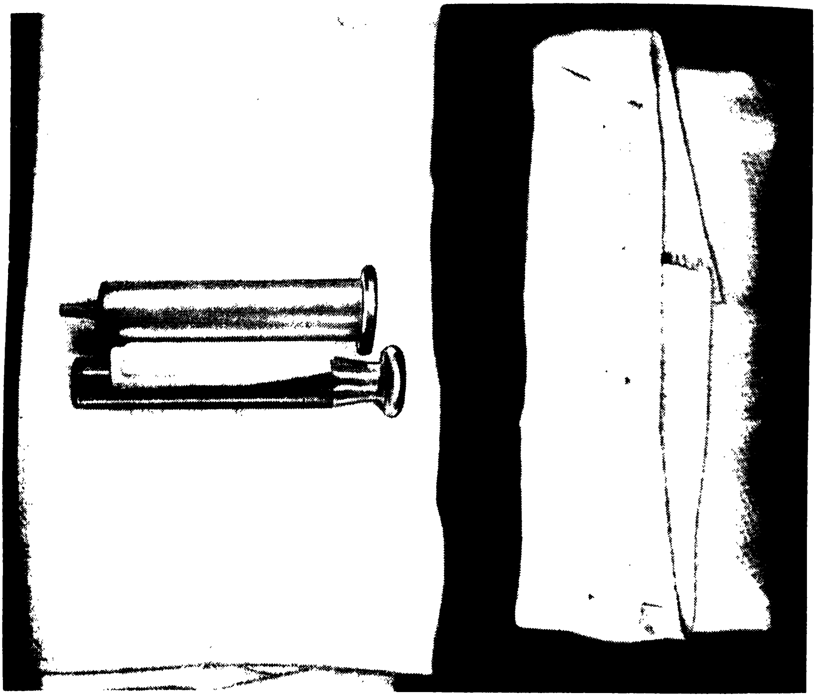

FIG. 70. This picture shows the more common method of preparing the syringe for sterilization. The plunger is removed and plunger and barrel, with or without the needle imbedded in gauze as shown, are wrapped in a towel or muslin cover. Sterilize at 320° F. for one hour.

Syringes. Because all moisture is eliminated, hot air sterilization is ideal for syringes, common practice in most laboratories. The more common method is to remove the plunger from the barrel and to wrap the barrel and plunger together in one muslin cover or towel. If desired, the needle can be folded in gauze and sterilized with the syringe.

Another method which has advantages is to assemble plunger and barrel with needle attached. Protect the point of the needle with a small test tube with restricted sides as described in Fig. 71. Use a large glass tube to contain the assembled syringe. Rest the end of the protecting test tube against a cushion of cotton in the bottom of the container and plug the open end of the tube with a tight fitting cotton stopper. Place the container vertically in the sterilizer so that if any barrel parts loosen up under the intense heat, they will not separate. They will seal again upon cooling. Sterilize for one hour at 320° F.

Because of unequal expansion of the barrel and plunger, breakage is sometimes experienced when assembled syringes are sterilized and to afford some protection, barrel and plunger may be contained in separate glass tubes otherwise handled as described above. These also should be sterilized for one hour at 320° F.

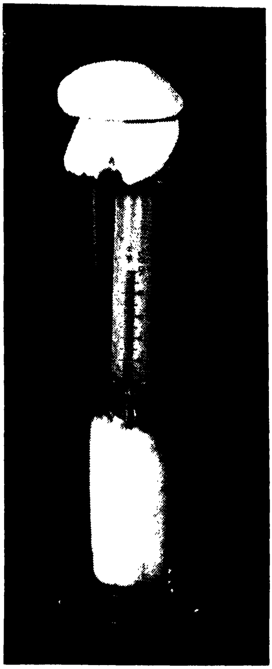

FIG. 71. This method of preparing the syringe for sterilization has its advantages, the syringe being completely assembled with the needle. The needle point is protected by a small test tube with restricted sides and the test tube rests upon a cushion of cotton in the container. The top of the cylinder has a tight fitting cotton plug held securely in place by a muslin cover. If better grades of syringes are used, very little breakage will be experienced. Sterilize for one hour at 320° F.

Suture Needles. When suture needles are sterilized in pressure steam there is no doubt about sterility but frequently very serious rusting occurs which is most difficult to explain. Scouring rusted needles requires a lot of time and tedious work. To avoid all rusting, use the hot air oven, sewing the needles into a gauze pack and wrapping with several layers of muslin. Sterilize for one hour at 320° F.

Scalpel Blades. Chemical sterilization is quite commonly used for blades and too frequently the performance leaves much to the imagination. There is usually no assurance of the strength of the solution for initial sterilization or that of the antiseptic solution in which they are stored. New blades can be sterilized once only in the hot air sterilizer at 320° F. for one hour. Repeated sterilization is not recommended because the intense heat of the oven will destroy the

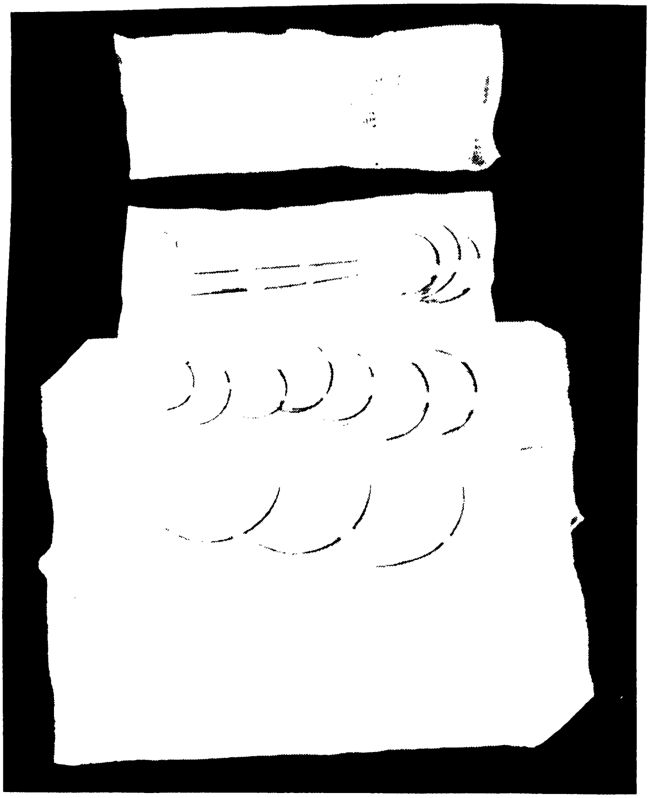

FIG. 72. Showing suture needles sewn into a gauze pack. They are folded and wrapped in muslin and sterilized in the hot air oven for one hour at 320° F. By this process much of the time consuming and tedious labor of scouring tarnished needles is eliminated.

temper. Place the blade in a small medicine bottle with only the tiniest wisp of gauze holding the blade from contact with the glass. Stopper the open end of the bottle with cotton loosely and wrap the bottle with muslin.

But there is no great advantage in hot air sterilization of blades over what can be routinely accomplished in the autoclave. Prepare the blade exactly as explained above, place the bottle on its side in the sterilizer to permit air to escape and sterilize for not less than 15 minutes. Routine sterilization with heavier loads of general supplies is permissible.

Zinc Peroxide. Special treatment is required for zinc peroxide because it will not withstand the normal hot air sterilizing tempera-

ture. Adjust the regulation of the hot air oven to 270–280° F. and maintain this temperature for four hours. The work can be done at night or during odd hours when the machine is not required for other purposes.

Adhesive Plaster. It is not advisable to attempt sterilization of adhesive plaster in the hospital. Manufacturers have developed special adhesive and procedures for sterilization which are quite intricate but reliable undoubtedly and if sterile adhesive is needed, it is best to purchase it in sterile form.

Artificially Waxed Silk Sutures. If artificially waxed silk sutures are secured in unsterile form, they should be sterilized in mineral oil. Since a considerable quantity of oil will be needed, it is best to first heat the oil to the sterilizing range which will usually take about two hours, depending of course upon the amount of oil required, then insert the suture material and continue sterilization at 320° F. for one hour.

If steam sterilized natural silk sutures are waxed in the surgery, the wax should be sterilized in the hot air oven at 320° F. for one hour.

Chapter XIII

Sterilization of Instruments and Utensils by the Boiling Method

Introductory to this general subject, it is desirable to point out that it is a debatable question whether the brief intervals sometimes permitted for boiling instruments and utensils are always adequate for the destruction of some of the more highly resistant bacteria. That there is some recognized uncertainty is indicated by the unusually prolonged periods of boiling or perhaps repeated boilings which invariably follow discovery in the surgery of some highly dangerous organism, such for example, as gas bacillus.

Of course these unusual precautions are most commendable for the sterilization of instruments and utensils used on infected cases, but they are just a bit inconsistent. All of the surgical sterilizing processes are supposedly based upon provisions amply destructive for these organisms—which may be encountered unexpectedly.

It is very difficult to determine exactly what the period of exposure for boiling instruments and utensils should be, to be perfectly safe. It is known, for example, that an instrument free from pus or blood in the grooves or crevices or joints will be rendered safely sterile by boiling for five minutes in 1% sodium carbonate solution. It is less easy to determine that an instrument has been completely cleared of pus and blood in its joints and crevices or to know just how much time may be needed for the destruction of organisms which may be thus protected against the action of the boiling water. It is absolutely certain that some extra time will be needed.

Because the difficult spore bearers are so rarely encountered in the surgery, operators are prone to attain a false sense of security that seems to justify short cuts. The fact that repeated laboratory tests show sterility after instruments have been boiled for five minutes does not by any means justify the adoption of such a limited period as a standard. That would be distinctly dangerous. Similarly it is not safe to permit emergency sterilization of instruments in brief intervals of time or by any short cut method which has not been thoroughly established.

One case on record serves to illustrate the general point. In a large hospital, the practice was established for sterilization of certain delicate cutting instruments, of rinsing them in scalding water after washing after which they were submerged in 70% alcohol for 20

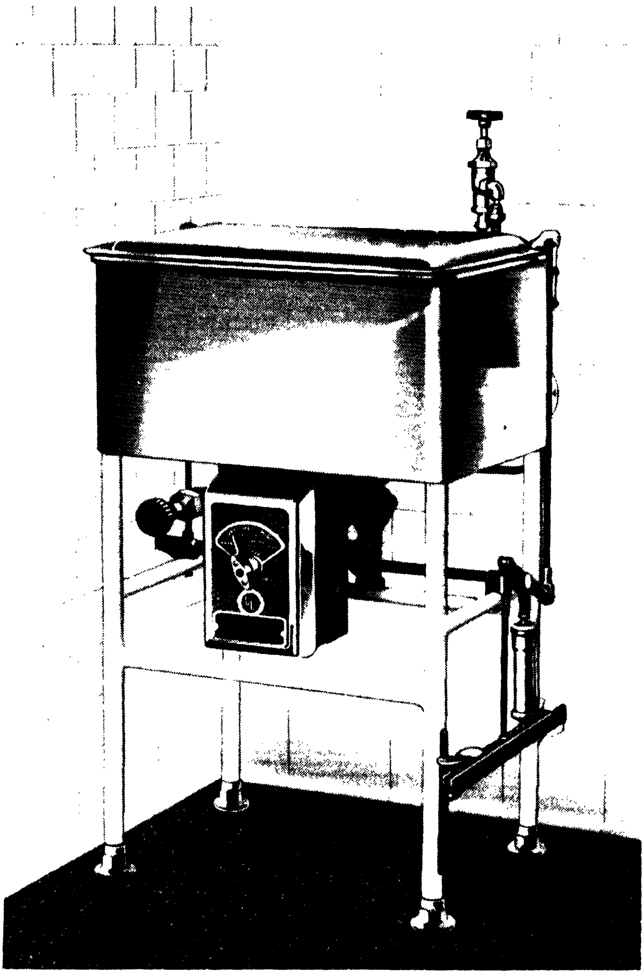

FIG. 73. Instrument sterilizer (boiler), electrically heated.

minutes. This method was followed for a long period of time successfully. Ultimately an accident case was brought into the surgery and shortly thereafter two patients died from infections of gas bacillus. A careful investigation brought to light that this had occurred from the use of infected cutting instruments. Exposure to alcohol for a full hour failed to render the instruments sterile when infected with this spore.

The Sterilizing Period For Instruments and Utensils. In large

hospitals where a great deal of surgery is done and where very high standards prevail, all instruments are boiled for 20 minutes and utensils are required to be completely submerged in boiling water for at least 20 minutes, preferably 30 minutes because of the possibility that with heavy loads some of the utensils will be exposed, in part, above the surface of the water.

In some hospitals where unusual attention is given to sterilization, if an emergency instrument is required, the nurses are permitted to reduce the sterilization period to 10 minutes boiling—only when so instructed by the surgeon.

In the sterilization of instruments, it is extremely important that the sterilizer be filled with water so that all parts of the instruments are well covered. It is not safe to allow any part of the instrument to

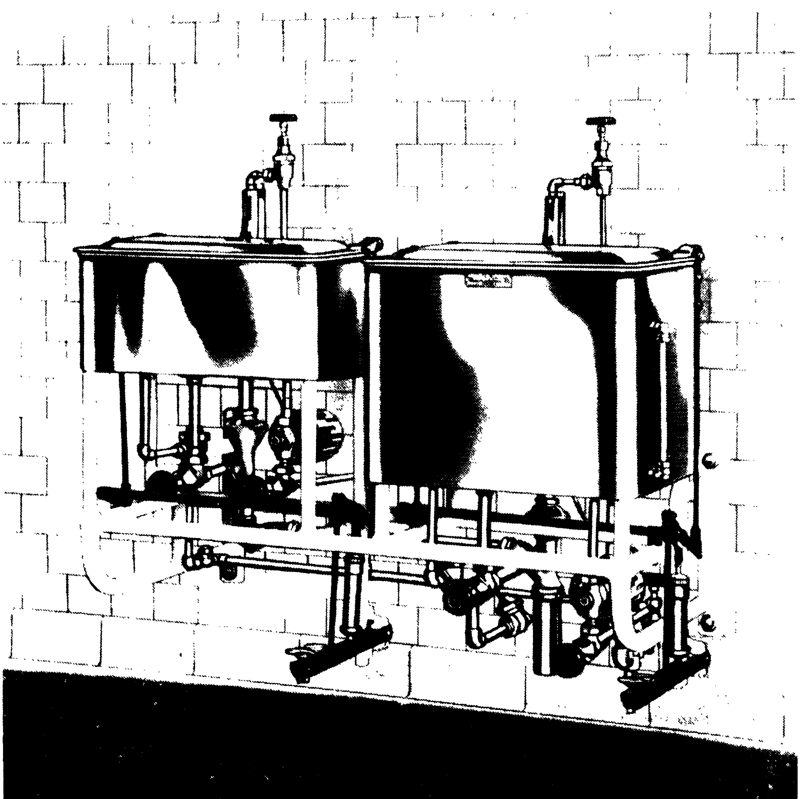

FIG. 74. A typical battery of instrument and utensil sterilizers for the utility room. Mounted on wall brackets.

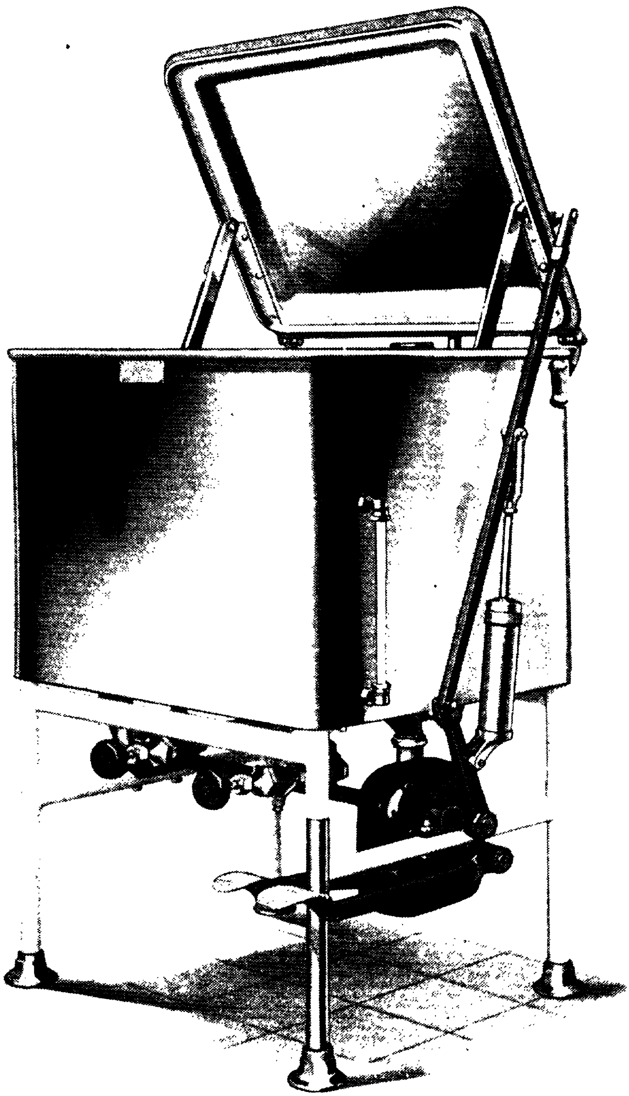

FIG. 75. Typical utensil sterilizer (boiler) steam heated.

be exposed above the surface of the water and to provide for this it is well to fill the sterilizer at the start so that there is at least half an inch of water above the instruments.

In many hospitals it has come to be quite common practice to sterilize utensils with the water level well below the tops of the utensils. This is not safe practice regardless of the fact that it may seem to be adequate. If the utensils are nested tightly as often occurs, there is grave danger that steam will not contact certain surfaces above the water sufficiently for sterilization. If the utensils are turned bottom side up, air will be pocketed in them which will interfere with steam contacts.

If the sterilizing period is 20 minutes, the requirements should be strictly enforced, that the utensils be completely submerged. Otherwise the period of vigorous boiling should be at least 30 minutes. It is quite true that the highest possible temperature is attained when water boils, even though the boiling action is moderate, but when parts of utensils are exposed above the surface of the water, vigorous boiling action is necessary to provide voluminous quantities of steam for contacting those surfaces.

Care of Instruments and Utensils Used on Infected Cases. Particularly those instruments and utensils which have been used on infected cases should be completely submerged, just as quickly as possible after use, in a 5% Lysol solution and allowed to soak for one hour before being washed. The purpose of this precautionary measure is to prevent spread of the infection to other places and to protect the nurse who washes the instruments from infection. This procedure should never be considered complete sterilization, it is merely protective to some extent.

It is much better, safer and faster, to use the pressure steam sterilizer for washing and sterilizing infected instruments as discussed in Chapter IX. Utensils also can be sterilized in pressure steam following use on infected cases to advantage.

The Purpose of One Per Cent Sodium Solution. It is claimed by recognized authorities that 1% sodium carbonate solution hastens the destruction of bacteria and spores distinctly, and for all instrument and utensil sterilization this is recommended. It is thought that the sodium also prevents rusting. This, however, is doubtful. The essential purpose of the sodium is to aid sterilization.

Carbolic Solution Is Recommended For Emergency Sterilization. It is claimed that the addition of carbolic acid in from 2% to 5% aids in the destruction of spores. It is suggested that this method be used for emergency sterilization of instruments, when the period of exposure is necessarily reduced to 5 or 10 minutes, and for the sterilization of all instruments or utensils used in septic surgery.

Definition of Boiling. The highest temperature that can be attained in boiling water in any open or non-pressure vessel, is 212 degrees F. at sea level. At higher altitudes water will boil at lower temperature, as for example, in Denver boiling occurs at 206 degrees F. It makes no difference how much heat is applied to the vessel—when ebullition occurs, the temperature will have reached its maximum. The application of more heat will simply increase the rate of evaporation, the violence of boiling.

In sterilizing instruments or utensils which are completely submerged in the water, it is not necessary or desirable to boil the water vigorously. The heat should be regulated to just maintain boiling condition, without creating dense clouds of steam, more or less of which will always escape into the room objectionably. Also, too vigorous boiling will rapidly deplete the water and require frequent refilling which is also highly objectionable.

If parts of utensils are exposed above the water in the sterilizer, then vigorous boiling is needed, to provide quantities of steam to thoroughly contact the exposed surfaces of utensils.

Instrument and utensil sterilizers may be vented to the atmosphere to dispose of excess steam or vapor, or they may be equipped with condenser vents in which cold water is permitted to flow through a condensing device at the rear of the sterilizer in such manner as to condense excess steam as fast as it forms. Neither of these methods makes any attempt to conserve heat, they merely dispose of the objectionable excess steam created by too vigorous boiling.

Another device is now available the "Excess Vapor Regulator" which can be applied to all boilers. It automatically regulates the rate of heating so that just enough heat is supplied to keep the water boiling without creating an excess of steam or vapor. With this device which is very dependable, no venting system is needed. Its use invariably results in a marked saving of power otherwise used in creating excess steam.

Avoid Chemical Sterilization Where Possible. Chemical sterilization is not considered good technique for general surgical purposes because the effectiveness is too uncertain. It is difficult to maintain the strength of any solution used more than once, similarly difficult to determine what the exposure should be, using any solution of unknown strength. Alcohol, contrary to the common belief, is not a good sterilizing agency. Bard-Parker Solution is probably as effective as any other chemical available. Regardless of the solution used, the washing process preceding the chemical sterilization should be most thorough to insure that all tarnish spots and grease are eliminated so that the chemical is not retarded in contacting the instrument surfaces.

Pressure steam sterilization of all kinds of instruments has now progressed so well, is so well defined, that it is possible and practical to sterilize even delicate eye instruments (with the possible exception of the cataract knife) to excellent advantage and with no apparent injury. In one hospital we have had the opportunity to follow this practice over a period of several years. The eye surgeons are thoroughly satisfied with the results. See Chapter IX for further discussion of the subject.

Sterilization of Syringes. While it is possible to sterilize syringes by boiling, hot air sterilization (Chapter XII) is much preferred. Lacking the hot air sterilizer, pressure steam sterilization is preferred.

For the boiling process, wash the parts as thoroughly as possible, wrap them separately in any soft, protective material, place them in the sterilizer before the water is heated to prevent breakage, boil for 20 minutes in plain water. Do not use soda.

Sterilization of Nail Brushes. Wash them most carefully, place brushes in the tray resting on their backs with no compression of the bristles, boil for 20 minutes. Maintain sterility by immersion in a mild solution of Lysol. Pressure steam sterilization is preferred. See Chapter IX for details.

The Cause of Rusted or Tarnished Instruments. Any steel instrument, poorly plated or one from which the plating has been worn off, will promptly rust if exposed to the atmosphere when moist. The rusting action will be increased if the instrument is exposed when hot and wet. Knowledge of this fact will suggest invariably the best method of rust prevention.

Instruments will not rust when completely submerged in water that has been boiled for a few minutes. For this reason, it is highly desirable to submerge used instruments as quickly as possible in a basin of sterile water or preferably 2 to 5% Lysol solution, until they can be washed, sterilized and dried.

Many tarnish spots on instruments result not so much from a tendency to rust as from the deposit on their surfaces of scale from the water, the same scale which coats the coils of the sterilizer and the bottom surfaces. It is difficult to remove this scale except by vigorous polishing. This formation of scale can be reduced appreciably by boiling the water for a full ten minutes before the instruments or utensils are put in. During this interval, a good part of the lime or other impurities in the natural water will have been deposited on the sterilizer coils, leaving less to attack the instruments or utensils.

It is quite evident that frequent draining of the sterilizer is most undesirable and that vigorous boiling which rapidly depletes the water is equally bad, because the addition of fresh water also adds to

the scale content. Use the water in the sterilizer throughout the day and drain and carefully clean the sterilizer at the close of the day.

There are available certain substances which can be added to the water in the sterilizer which will prevent in some measure at least the deposits of scale. None of these substances will remove the chemical impurities from the water. They may retard or prevent the formation of scale. None of the known scale softeners will apply to all kinds of water. It is thought that the simple precautions outlined above, that is, boiling the water for ten minutes before putting in the instruments and avoiding the frequent refilling of the sterilizer will accomplish the most practical purpose.

In one hospital, at least, where a great deal of work is done, the engineer is required at weekly intervals to clean the sterilizers thoroughly. The sterilizer is filled with water containing half a pint of coal oil and boiled vigorously for half an hour. Then the coils and all scaled surfaces are cleaned. The coal oil softens the scale so that it can be removed more easily.

There are other preparations which can be used to soften the scale so that it can be removed, but regardless of the method employed, every sterilizer should be carefully cleaned, preferably by a good mechanic, at weekly intervals. The building up of heavy scale is most objectionable from every standpoint. If the sterilizer is heated by electricity, an accumulation of scale about the heaters very frequently causes burn outs.

Pressure Steam Sterilization of Instruments and Utensils Emphatically Recommended. It can be conservatively stated that pressure steam sterilization of these materials can be accomplished, with greater safety, in half the time or less, necessary for boiling. This coupled with the fact that all scale formation is eliminated when pressure steam is used, makes a most unfavorable comparison for the boiling process. It may be economically necessary to continue the boiling operation for floor work where comparatively little sterilization is required, but for all operating departments, pressure steam closely approaches the ideal. Even for floor work, the need for instrument and utensil boiling is largely eliminated when Central Sterilization of supplies is introduced.

Scale formation on instruments and utensils routinely boiled has never been successfully eliminated. With the most careful scrubbing and scouring, scale will adhere to surfaces, especially in joints and crevices. This is often demonstrated when instruments which previously have been boiled routinely are first subjected to pressure steam sterilization. Until they have been through the pressure sterilizer several times, tarnish spots will appear which operators are inclined to believe is rust. It is not rust but a gradual disinte-

gration of scale which deposits on surfaces when the instruments cool. Once this scale has been eliminated, no more will be encountered if the instruments are no longer boiled. Obviously less cleaning and polishing are required for pressure steam sterilized instruments.

Similarly, utensils which have been boiled in routine practice accumulate a most unsightly coating of scale on all surfaces. This coating will disintegrate under steam sterilization and the surfaces will remain bright and clean.

Chapter XIV

Water Sterilization

Requirements for Sterilizing Water. There is little difficulty involved in rendering tap water completely sterile. Minimum requirements as quoted elsewhere in this text are:

Maintenance at 250° F. for one minute
Maintenance at 240° F. for four minutes
Maintenance at 230° F. for ten minutes

It is obvious that dried and highly resistant spores are not encountered in water and there is no problem, as in sterilizing dry goods, of penetration of dense masses of materials. The gauge of sterilization is the thermometer and it indicates the water temperature directly. We have the accurately measured degree of heat and the water itself furnishes the moisture factor.

As in the sterilization of dry goods, it is appropriate to establish the sterilizing temperature range at 240 minimum to 250–254° F. maximum, timing the exposure when the thermometer indicates 240° F. Since there are no variables with respect to the character of the load, as in dry goods sterilization, it is perfectly practical and safe to establish the sterilization period at ten minutes at the above mentioned range of temperature.

How Sterile Tap Water Differs from Sterile Distilled Water. Sterilized tap water must not be confused with distilled water. Both when freshly prepared are sterile, but the tap water will contain chemical impurities and pyrogens. Sterilization will remove neither the chemical impurities nor the pyrogens. Properly made, freshly distilled water, on the contrary, will be essentially free from both. Therefore, for the preparation of intravenous solutions, only freshly made distilled water should be used.

Inadequately Filtered Air Contaminates Sterile Water. The real difficulty experienced in the maintenance of a sterile water supply has to do, not with the initial sterilizing performance, but with the problem of keeping the water free from contamination. On this point there has been much misunderstanding. Some of the really dangerous sources of contamination are commonly ignored.

With the usual type of water sterilizer found in every surgery, recontamination of the sterilized product begins when the water cools and continues until the reservoir has been emptied. Hot water, in cooling, absorbs air until it has reached atmospheric temperature

and with every withdrawal of water from the reservoir, an equal amount of air is drawn in. This absorption of air and the air contacts permit certain definite contaminating influences, unless the air is perfectly filtered freed from all dust. Many sterilizers make no provision for filtering incoming air at all, others provide an entirely inadequate cotton filled filtering cup. In either case, there is a contaminating influence which cannot safely be ignored.

A quite common type of air filter is shown by Fig. 76. It consists of a small metal cup mounted at the top of an automatic valve on the dome of the reservoir. The valve closes approximately tight but rarely completely tight, when the reservoir is subjected to internal pressure as in sterilizing. It opens freely to relieve vacuum when the water cools and when water is withdrawn, for the intake of air. The metal cup at the top is supposedly filled with fresh cotton daily through which incoming air must pass. Actually, the cotton does not serve well as a filter because it is invariably moistened by steam which escapes during sterilization, causing it to shrink away from the walls of the cup. When moist, cotton becomes comparatively dense so that air can be forced through it only with difficulty. The result is that there is little filtration of air but there is an intake of dust and condensate from the metal cup.

Some interesting experiments are quoted, relating to the shrink-

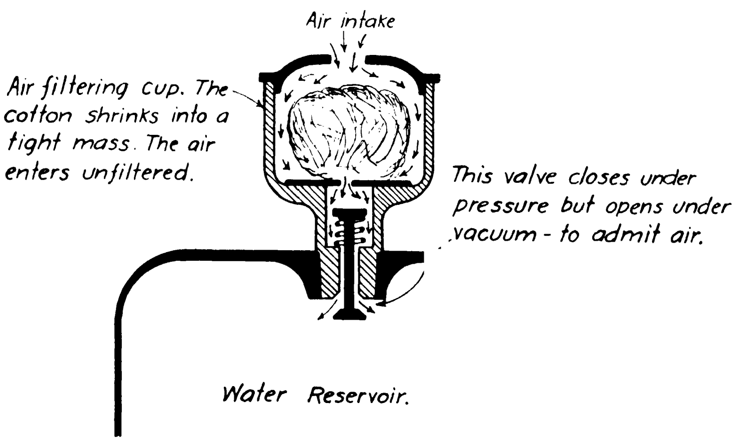

FIG. 76. A common type of vacuum release valve and air filtering cup. The cup is supposedly filled with fresh cotton daily, through which incoming air is required to pass. Steam which always escapes from the valve during sterilization wets the cotton stopper and causes it to shrink into a more or less dense mass through which it is difficult to force air. Condensate forms in the unsterile cup and in the cotton and drains back into the sterilizer. There is very little filtration of air.

age of water in cooling and the contaminating influence of air contacts.

A 25 gallon reservoir of water was heated to 250 degrees F. and then allowed to cool to atmospheric temperature. The reservoir was so arranged that all air was taken in through a glass water trap. Twenty-four hours after the heat was turned off, air bubbles were still being drawn in visibly through the water trap—in appreciable quantity.

The air in-take to a 15 gallon reservoir was required to pass through a sterilized flask of specially prepared media as the reservoir

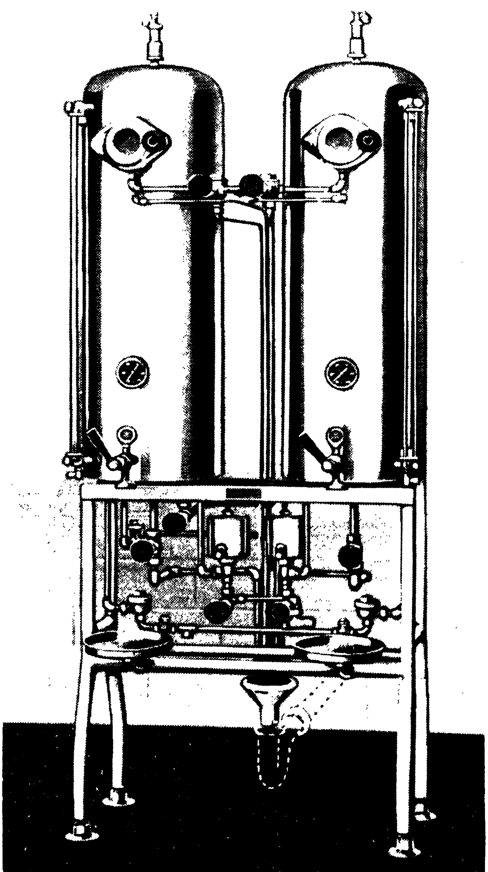

FIG. 77. Typical modern water sterilizers—steam heated.

was drained. In the culture media were found numerous colonies of vegetative forms of pathogenic bacteria and some spore forms which were not analyzed. All air, unless it has been thoroughly filtered, does carry more or less dangerous organisms, for which reason all surgical supplies are wrapped in protective covers of muslin. There is nothing new about the principle but insufficient thought has been given to the detail of protecting sterile water, in this respect.

Sterile Muslin Covers Should Be Used for Covering All Air In-take Valves of the General Type Illustrated by Fig. 78. In one hospital where infections had occurred, it was found that the sterile water showed contamination every time tests were made, after the water had been standing for a few hours. The filter valves were checked, the reservoirs were taken down and cleaned, still every test made after a few hours showed contamination. The apparatus was discontinued in use for several days. Then it was decided that the source of infection must be the air in-take system. The vacuum breaker cups were cleaned thoroughly and covered with three thicknesses of sterile muslin, bound on tightly about the base of the cup, much the same as the older method used for covering stoppers of solution flasks. Thereafter in numerous tests made after the water had been standing for 24 hours there were no growths.

Any Water Filter Serving Two Reservoirs Is a Constant Source of Water Contamination. Fig. 78 shows the common method of valving a single stone type filter so that it is made to serve a pair of water sterilizer reservoirs. To fill either reservoir valves 1 and 2 or 1 and 3 must be opened with valve 4 closed. Water will then pass

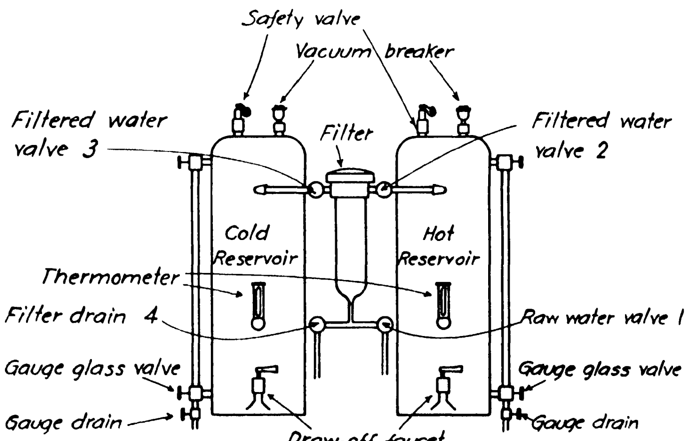

FIG. 78. The common method of valving combination stone type filters.

through the filter to the reservoir. When sufficient water has been filtered, valves 1 and 2 or 1 and 3 are closed and (supposedly) valve 4 is opened, so that any leakage from valve 1 will be permitted to escape into the waste rather than to exert pressure on valves 2 and 3 which might leak slightly and permit the contamination of sterilized water. If these control valves are carelessly handled, if the operator forgets to open waste valve 4 after filling, there is grave danger of contamination.

Valves in This Service Are Always Subject to Slight, Undetected Leakage. Any type of valve known is subject to some leakage

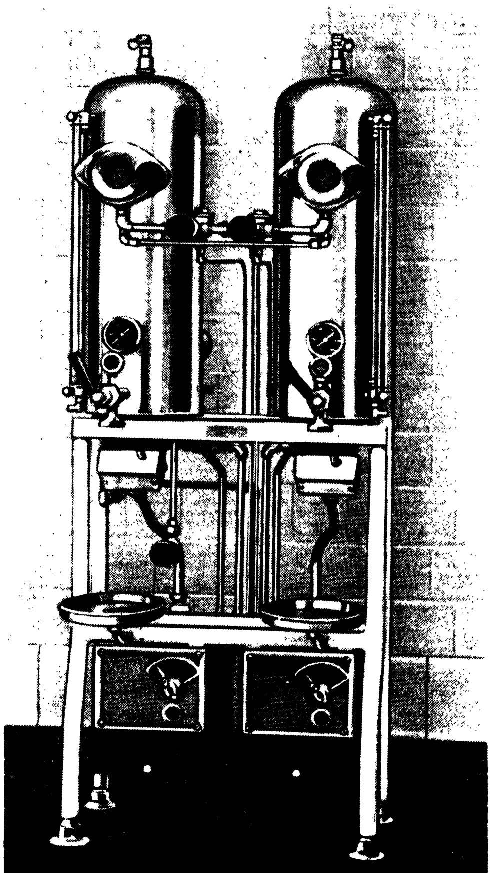

FIG. 79. Typical modern water sterilizers—electrically heated.

after service. This is evident from the condition of the average lavatory faucet. After a time the disc which forms the closing medium becomes worn or distorted in shape and a gradual slow leak develops. With the lavatory faucet the leakage is immediately seen but on filters of this type the leakage cannot be seen, nor will it be detected until it has progressed to the point where a considerable volume of water flows which will show up on the gauge glass. The slow, drop-by-drop leak into the sterile reservoir may be very serious, depending upon the condition of the raw water supply. Valves 2 and 3 are subjected to the unusual strain of controlling the cold water in-take, after which they are subjected to the hot steam from the sterilizer which hardens or cracks the discs.

Stone Type Filters Become Foul in Use—Cannot Be Sterilized. The filter is a hollow cylinder of natural stone or a synthetic product of similar characteristics so mounted in its case that raw water surrounds it, filters through to the hollow interior, and is conducted through valves 2 or 3 to the reservoirs.

All of the solid impurities in the raw water are deposited upon the surface of the stone and in its pores. These stones, unless broken, are continued in service indefinitely—for months or years. They are taken out and scrubbed at intervals of days or weeks, when slow filtration indicates that they are clogged with mud or sediment. Only the surfaces can be cleaned, they cannot be sterilized because steam would destroy them. The accumulated slime on the surfaces of the stone and in its pores, easily detected by examination, furnishes an excellent culture media for bacteria and the filter is maintained, due to its location near the hot sterile reservoirs, at temperatures which promote growth of bacteria. It is evident that any slow leakage through this unsterile mass to a sterile reservoir would be far more contaminating than the natural raw water. The pores of the stone are too coarse to filter out bacteria.

Either Sterile Reservoir May Be Contaminated if the Drain Valve 4 Is Left Closed. If both reservoirs are sterile and drain valve 4 is left closed then if valve 1 should leak slightly, the full water pressure would gradually be exerted on valves 2 and 3. If they should also leak slightly, the polluted filter water would escape through to the sterile water drop-by-drop. This can be detected only when the leakage is sufficiently great to show up on the gauge glass. Observation will disclose that more often than not, valve 4 is left closed after the filter has been used.

One Sterile Reservoir Is Easily Contaminated While the Other Is Being Filled with Water. Refer to Fig. 78 and assume that the left hand reservoir is being filled and that the right hand reservoir is sterile. This is common practice. If valve 2 (supposedly closed

tight) should leak slightly, the pressure of raw water exerted on the filter would cause an intake to the sterile water, of the unsterile product. The only safeguard against this occurrence is constant inspection of the valves 1, 2 and 3, to insure that they are in perfect condition and most careful use of the valves to insure tight closures.

Fig. 80 shows a method of partially protecting against sterile contamination through the filtering system. A small pipe is conducted from the filter case to an exposed funnel in full view of the operator. When filling either reservoir there will be a constant flow of water through this funnel—a telltale stream of small volume which will be

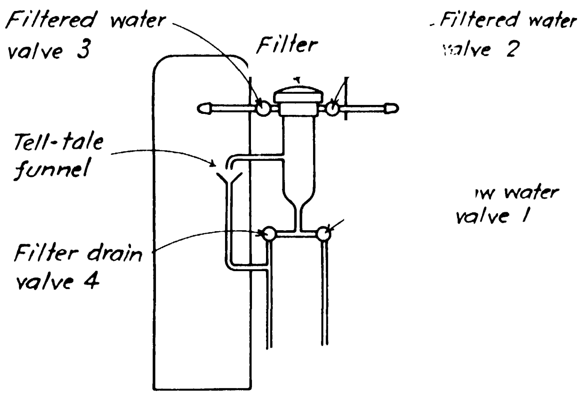

FIG. 80. The overflow method of detecting leakage of raw water to the filter. When either reservoir is being filled with water a stream of water will escape through the funnel, visibly to the operator. If water leaks through the funnel at any other time, that indicates that the raw water intake valve to the filter is leaking.

wasted. If any water escapes at any time when neither reservoir is being filled, that indicates that raw water is leaking into the filter through valve 1. Unless the leakage is very fast, the telltale line will exhaust all the leakage before it rises in the filter to the outlets to the sterile reservoirs. This method offers no protection in the case where one reservoir is being filled when the other is sterile.

Gauge Glasses Should Be Steam Flushed. Water contained in the gauge glass is not subjected to the sterilizing influence of the heat applied to the reservoir. If it is not flushed out during or following sterilization, it will later contaminate the sterile product.

Nearly all of the older models of water sterilizers have valves on the gauge fittings with which the gauge can be closed off from the reservoir and the bottom gauge fitting has also a drain cock with which the contents of the gauge can be flushed. The work should be

done just at the close of sterilization, before the heat is turned off. Close the valve from the bottom of the gauge to the reservoir and open the drain cock under the gauge fitting. Steam from the dome of the reservoir will flow through the glass and in 10 to 15 seconds will thoroughly steam cleanse the glass. When the drain cock is closed and the valve to the reservoir opened, the gauge will refill to the level of the water in the reservoir, with sterile water.

Some of the newer water sterilizers have automatic gauge glass cleansers which cause a circulation of water from the reservoir through the gauge glass throughout sterilization, by a percolating process.

Clean Interiors of Water Reservoirs at Frequent Intervals. Practically all natural water contains certain products in solution which will pass through the filter. The application of heat causes these to deposit in the form of scale on the coils of the heater or on the bottoms of the reservoirs. This scale sometimes breaks up into small particles and the gradual accumulation will deposit in the reservoirs.

These materials are doubtless sterile but in other respects they render the water unfit for use. As soon as any discoloration of the water is noted or if particles of scale come through the faucet, that is clear indication that the reservoir needs cleaning.

Only a skillful mechanic should be permitted to clean the reservoirs. It is necessary to remove the base and all fittings so that they will not be injured in handling. The surfaces of coils, and interior surfaces of the reservoir and all pipe openings should be scraped clean and the parts rinsed free from particles before reassembling.

Clean the Water Filters at Least Twice Each Week. The surface of the stone and its pores will contain all of the solid impurities found in the natural water. If allowed to accumulate for days or weeks, these become an actual menace because they collect bacteria and furnish a breeding ground for them.

Every filter stone should be removed from its case at definitely scheduled intervals of two or three days, and its surfaces should be scrubbed with a stiff brush until the surface discoloration has been removed. If the brush will not remove the discoloration, the stone should be scraped with an old knive until clean surfaces are exposed. At the best, this cleansing is only surface deep. There will be some contamination all through the open pores of the stone which cannot be removed. It is good practice to replace stones as soon as they show signs of interior discoloration.

Cleansing of Draw-Off Faucets. At the close of the sterilization period, before turning off the heat, hold a pitcher under each faucet and permit the scalding hot water and steam to flow through as

voluminously as possible for 10 to 15 seconds. This serves to sterilize the mouthpiece of the faucet as well as that can be done by any process.

Some hospitals require mouthpieces of faucets to be flamed before use. This is a troublesome detail and it is exceedingly questionable whether the flame, as ordinarily applied, ever contacts the inner parts of the mouthpiece. Blowing out the faucets with steam is much better practice.

Other hospitals cover the mouthpieces of faucets with sterile muslin or gauze covers. This is less protective than to omit the covers. The gauze or muslin is larger, it is porous, it is subject to air and contact contamination. Whatever impurities may find their way into the covers will drain out into the pitcher when water is withdrawn.

Resterilize Each Water Reservoir Daily. Water sterilizers equipped with any form of combination water filter, serving both reservoirs, should be resterilized daily, because the opportunity for slow but continuous recontamination through the filter constitutes too great a hazard to permit the safe assumption, without proof, that it has not occurred. The degree of contamination, if it does occur, increases with time. It might not be great in a few hours but the accumulated leakage of a day might become dangerous.

Individual Water Filters, One for Each Reservoir, Combined with Adequate Filtration of Incoming Air, Eliminate the Common Recontamination Hazards

There is an individual water and air filter for each reservoir controlled entirely through one valve. The filter is so constructed that it can be sterilized by live steam and the sterilization process is automatic in performance. Both the water filtering element and the air filter are cleansed by a back flow of steam while water is undergoing sterilization.

The water filtering element is made from several separated discs of a specially prepared fibrous substance, quite flexible, which will withstand the action of steam in sterilizing without losing its filtration properties. The water filtering element is mounted in the filter case behind a glass cover through which the operator can plainly see the passage of water to the reservoir.

The air in-take to the reservoir occurs through the same filter case and might be drawn back through the water filter element except that, like cotton when moist, it is so dense that air can be drawn through only with pressure. For the filtration of air a secondary element is provided made from a very tightly compressed mass of monel metal wool which is maintained in a moist condition. Its air filtering properties are excellent and, notably, the element requires

no attention from the operator. It is backwashed by steam with every water sterilization.

The complete water and air filtering assembly is automatically subjected to sterilization by steam, a cleansing and sterilizing back flow of steam direct from the dome of the reservoir, each time the water undergoes sterilization. This is precisely the sterilizing effect to which surgical supplies are subjected in pressure steam sterilizers.

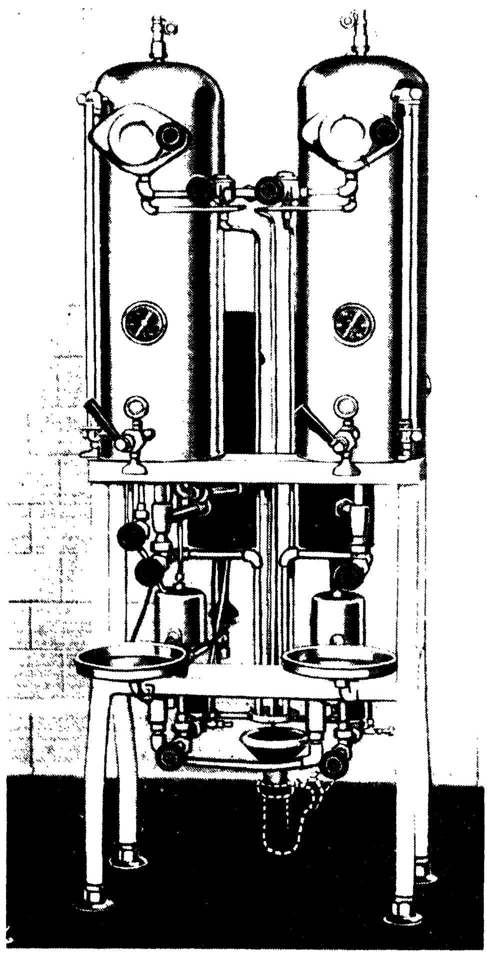

FIG. 81. Typical modern water sterilizers—gas heated

The performance of the filter is controlled by a single valve of un usual design, which when closed opens by positive action a second port in the rear, leading through a thermostatic valve to a funnel vented waste line, rather than to the water reservoir. This affords the very important protection of the sterile water from contamination through a leaky in-take valve. If the valve does leak, and all valves become leaky after long service, the leakage is discharged into the waste—not to the sterile reservoir. When this valve is opened for the intake of water to the filter, the by-pass connection to the waste is automatically closed so that there is no wastage of water.

When the reservoir has been filled with water and heat is applied, the steam which forms in the dome of the reservoir is conducted through the filter, serving as a backwash, to a thermostatic valve which remains open until hot steam causes it to close, just the same as the air eliminating system on modern pressure steam sterilizers. Thereafter, throughout the sterilizing period, the filter is maintained at steam sterilization temperature.

When the reservoir has been sterilized and the water begins to cool, steam in the dome of the reservoir condenses and creates a shrinkage effect tendency to form a vacuum. This is relieved by the air filtering device and filtered room air is permitted to enter the reservoir. As water is withdrawn from the reservoir, it is replaced with filtered air.

By this simple system which can be applied to any reasonably modern water sterilizer, the common and otherwise almost unavoidable sources of sterile water contamination are eliminated. The water filtering elements require no mechanical cleaning at all, they are automatically cleaned to the greatest possible degree by the back flow of steam in sterilizing. They will require replacement at intervals of two or three months, ordinarily, when they are seen through the glass front to be discolored. The air filtering element is permanent, requires no attention from the operator. The back flow of steam removes the particles of dust which collect in it.

THE RECOMMENDED ORDER OF PROCEDURE IN STERILIZING WATER

Fill the Reservoir With Filtered Water. If the sterilizers are equipped with individual water filters, as described above, this necessitates no attention other than to open the one valve which admits water to the reservoir until a sufficient quantity of water has been collected.

If the older type of water filter is provided, great care must be exercised in the control of the four valves as outlined in the text, to see that they are opened and closed in the proper order and without confusion of the valves. The supervisor should require frequent in-

spection of the valves by a competent mechanic to be sure that their discs are in perfect shape for tight closure. Operators should be instructed to close all water valves tight after use because of the possibility of slow leakage otherwise.

Cleanse and Put Fresh Muslin Covers On Air Intake Valves. This will not be necessary, of course, if the individual water and air filters are used. Otherwise, before turning on the heat to sterilize, remove the old valve covers, remove any lint which may adhere to the top of the valve or the filtering cup, cover the valve or cup completely with three layers of sterilized muslin and bind the skirt of the cover tightly about the restricted neck of the valve or cup.

Turn on the Heat. Maintain the water at 240–254° F. for ten minutes only. Higher temperature or more time will do no harm but will add to the cost of operation, an item of considerable importance especially when gas or electricity is used.

Just Before Turning Off the Heat

First cleanse the draw-off faucets by permitting hot water and steam to escape into a pitcher for 10 to 15 seconds. Flaming the faucets or covering them with sterile gauze or muslin is not recommended as covered by the foregoing text.

Unless the sterilizer is equipped with automatic gauge glass sterilizers, steam flush the gauge glasses. Close the valve at the bottom of the gauge. This will close off the connection to the reservoir. Then open the drain cock underneath and permit the gauge to drain into a pitcher and steam to flow through for 10 to 15 seconds. This will cleanse the gauge glass and it will thus be filled with sterile water from the reservoir. Then close the drain cock and open the valve to the reservoir.

If the sterilizer is equipped with automatic gauge glass cleansers, the water from the reservoir will percolate through the glass visibly during sterilization. This should be checked at least once during each water sterilization by the operator. If no flow of water can be detected, that will indicate that the percolating system is clogged. Resort immediately to the mechanical process described above, until a mechanic can be called to remove the clogging effect in the percolator.

Resterilize After 24 Hours. This is particularly important if the sterilizer is equipped with any type of combination water filter which serves two reservoirs because of the possibly slow and undetected intake of raw water through the filter as explained elsewhere.

A highly dangerous source of sterile water contamination is found in drain lines conducted directly to the waste system without intermediate air breaks. This is discussed in Chapter XVII. In a test

made with such a sterilizer also equipped with the old style stone filters, cultures taken from the residue on the surface of the stone filter showed a heavy growth of pathogenic organisms, including B. coli. The obvious source of this organism was the un-broken connection to the sewage system.

Chapter XV

Bedpan and Urinal Washing and Sterilization

Normally we think of "sterilization" as meaning the complete destruction of all pathogenic organisms and this is a true definition as applied to all surgical processes, of course. But in sterilization of bedpans and urinals, another meaning is intended, certainly from the practical standpoint. In this case the intent is to rid the utensil of the communicable disease organisms, all of which are found in the vegetative types, all relatively easy to destroy in a brief interval of time in direct contact with atmospheric steam, that is, steam not under pressure.

To illustrate the point in another way, one could not sensibly object to the use of a new bedpan or urinal subjected to no sterilizing process other than washing. The utensil would not, of course, be surgically sterile but it would be perfectly suitable to serve its normal purpose.

The following report of tests by Dr. Armstrong, Pathologist, Hamot Hospital, Erie, Pa., is enlightening with respect to the effectiveness of steam in ridding a bedpan of the type of organism it is necessary to destroy in bedpan and urinal sterilization.

Dr. Armstrong's Report

In testing the germicidal efficiency of your Aeroflush Bed Pan Sterilizer, the following technique was employed:

Bacteria: Standard strains of Staphylococcus aureus and Bacillus coli.

Pans Inoculated: Ordinary white enamel bed pans that are in use in our hospital wards.

Sterilization Time: Thirty seconds, sixty seconds and ninety seconds.

Media Employed for Subculture: Plain bouillon and blood agar plates.

Site of Inoculation: In inoculating these bed pans with the strains of the organisms mentioned above, points of inoculation were selected that were underneath the lip of the pan in concealed locations, and in three of the experiments roughened areas where the enamel was chipped off were used as inoculation sites.

Experiments Were Conducted as Follows: The bed pans were first sterilized to free them from any sporebearing bacteria. Different areas on the surface of the pans were inoculated from fresh cultures of Staphylococcus aureus and Bacillus coli. The pans were then placed in the Aeroflush and steam turned on for the required period. At the end of this period the door was immediately opened and the pans removed and subcultures made.

Results:

Exposure in Aeroflush	*Staphylococcus aureus*	*Bacillus coli*
30 seconds	Sterile	Sterile
60 seconds	Sterile	Sterile
90 seconds	Sterile	Sterile

The above experiments were repeated by me on six different occasions, and in each case the subcultures have always been sterile.

Very truly yours,
(Signed) E. L. ARMSTRONG, M.D.,
Pathologist
(December 14, 1934)

Modern apparatus for washing and sterilizing bedpans has been vastly improved in recent years to facilitate the completion of this most offensive duty the nurse must perform. With the apparatus shown in Figs. 82 and 83 the nurse brings the soiled pan or urinal to the machine, presses the foot pedal to open the cover, inserts the utensil within the flexible arms and removes her foor from the pedal. The cover closes automatically and at the same time the utensil is emptied. Another foot pedal is now pressed and a standard flushing valve is tripped which subjects the utensil to a very thorough flushing with cold water. Flushing continues for approximately 20 seconds. Now the operator presses with her hand (or forearm if hands are soiled) on a lever operated steam valve which admits live steam to direct contact with the utensil for sterilization. One or two minutes exposure is ample to rid the utensil surfaces of the communicable disease organisms. The steam valve closes automatically when the pressure is released.

The work is complete in approximately two to three minutes and the pan can be removed, for immediate use or storage.

A second method of doing this work involves a machine exactly like that described above except it does not have the steam sterilizing feature. The bedpan or urinal in this case is flushed in the washer, then it is removed to the bedpan or urinal steaming sterilizer shown at the right in Fig. 84. This machine is very similar to the commonly used utensil sterilizer of the boiling type. It is of size suitable to hold 5 bedpans resting vertically in a removable tray rack.

Some authorities prefer this system of handling bedpans and urinals since it releases the nurse immediately after the pan is washed, a matter of about 20 seconds, for other duties. When 5 pans have accumulated in the bedpan sterilizer, they are subjected to steaming or boiling as may be desired for a brief interval, then the rack of sterilized pans is removed to the wall rack adjacent for storage. Steaming or boiling for five minutes in the sterilizer is adequate for the purpose. When pressure steam is available, the direct steaming type is preferred to boiling because the operation is somewhat faster and because steaming leaves no scale deposits on the utensils. If only gas or electricity is available for heating, then the sterilizer must be of the boiler type, obviously.

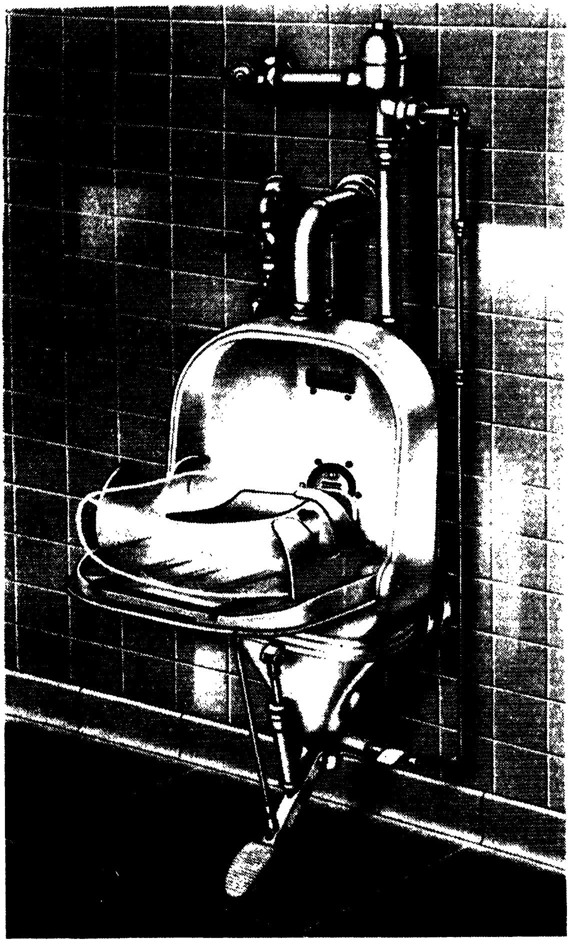

FIG. 82. Wall mounted bedpan and urinal washer and sterilizer showing cover opened and a bedpan in the flexible holding arms.

Experience dictates that one bedpan and urinal washing and sterilizing apparatus of either of the types described will serve about 15 patients very satisfactorily and that is used as a general guide in the arrangement of utility rooms in new construction. However, there are many installations in successful operation where one unit for washing and sterilizing is made to serve as many as twenty to thirty patients. That, of course, is not the best practice. Where an abnormal number of patients must be served by one washing and

FIG. 83. Built-in type bedpan and urinal washer and sterilizer. This type occupies slightly less floor space, performs exactly the same as the wall suspended type.

sterilizing unit, it is probable that the combination of bedpan washer with separate sterilizing unit is more practical because some time is saved when the nurse can release the washer for another pan within a matter of 30 seconds, whereas washing and sterilizing all in the one machine requires about 3 minutes.

The type of washer and sterilizer illustrated herein incorporates certain features of design which have done much to eliminate the serious objections inherent in earlier designs. One outstanding fea-

ture is the loose fitting cover which serves a two-fold purpose. The cover is baffled on the inside so that in normal usage there is no leakage of water.

The loose fitting design of cover serves as an overflow so that polluted fluids can rise in the chamber, under adverse conditions, not appreciably higher than the bottom of the cover. That constitutes a highly important sanitary protective feature which is thoroughly discussed in Chapter XVII.

Similarly the loose fitting cover serves to admit room air to the chamber for continuous aeration. The effect is that of a chimney on any fuel consuming stove or furnace. Room air enters, entrains with odors or vapor and passes up the vent stack. Lacking the loose fitting cover or its equivalent opening for air intake, odors are trapped in the chamber offensively.

In former years attempts were made to build apparatus in which bedpans, urinals and feces could be sterilized before releasing to the drainage system. Such machines never proved to be satisfactory. Sanitary provisions were completely ignored. The need for such provision has largely been done away with in the modern city sewage disposal plant. When it is necessary to sterilize feces or urine, the only practical method available is use of a suitable chemical.

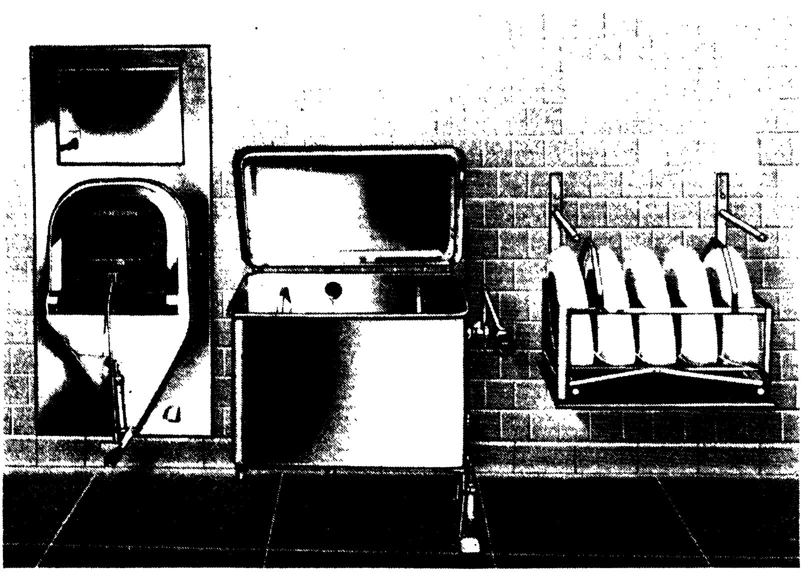

FIG. 84. Utility Room Group, showing Bedpan or urinal washer (only) with bedpan steamer and wall rack.

CHAPTER XVI

Pasteurization of Milk and Milk Bottle Sterilization

In defining Milk Pasteurization, we have chosen to quote from Principles of Bacteriology and Immunity by Topley and Wilson, Second Edition, published in 1937. Under Heat Treatment of Milk they state:

> "The dangers of infection of milk from cattle, from the human personnel, and from water are so great that we shall not be overstating the case if we assert that no raw milk can be regarded as perfectly safe for human consumption. Clearly we must interpret this axiom with discretion, remembering always that the stringency of our precautions must be commensurate with the size of the population at risk. It is very difficult to assess in any particular instance the real danger run by persons consuming a given milk supply, and our safest course is therefore to insist as far as possible that all pathogenic organisms shall be destroyed by some form of heat treatment.
>
> "Pasteurization is by far the most satisfactory method for this purpose. In this country the process consists in raising the milk to a temperature of 145-150° F., holding it at this temperature for 30 minutes, and immediately cooling it to 55° F. or below. If this process is carried out in properly designed plant free from mechanical defects (see Scott and Wright 1935, Dalrymple—Champneys 1935) and supervised by intelligent and conscientious operatives, it can be relied upon to destroy all pathogenic organisms in the milk"

We quote again from the same text:

> "From a public health point of view—there are strong reasons why all milk intended for consumption in the liquid state by a community of any size should be submitted to pasteurization, the process being, of course, adequately controlled by the appropriate supervising authorities. There is reason to believe that if pasteurization was rendered compulsory and universal, milk-borne disease would practically cease to exist.
>
> If pasteurization is impractical, then the milk should be boiled in the individual household. The most satisfactory way of doing this is to bring it to the boil in a closed vessel, preferably a double saucepan, and cool it immediately to as low a temperature as possible."

When the institution finds it impractical to secure milk from the producers that has been satisfactorily heat treated, it becomes necessary to pasteurize the raw product in apparatus suitable in size for the requirements. Such apparatus is available in a combined unit which is used not only for pasteurization but also for bottle sterilization. The machines are similar in construction to the usual instru-

ment or utensil boiler and are available in more or less standard sizes ranging in capacity from 36 to 288 (4 or 8 ounce) bottles. The principle of pasteurization is carried out by placing the filled bottles in suitable tray carriers in the machine which is then filled with water to the height of the bottle necks. While a thermometer is provided on the side of the machine which denotes the (water) temperature, it is necessary to measure the actual milk temperature which is done by inserting a thermometer in one of the bottles. It is easily possible to so correlate the temperature readings of the two thermometers that after a bit of experimenting, use of the thermometer in the milk is not required.

The usual machine is equipped with an overflow outlet which prevents filling of the chamber with water beyond the height of the bottle necks and following pasteurization, the hot water is permitted

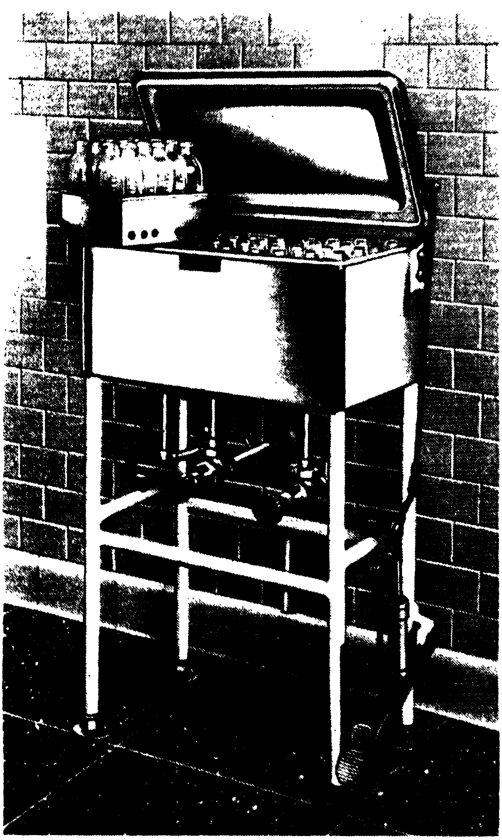

FIG. 85. Typical steam heated Pasteurizer and Bottle Sterilizer 36 Bottle size.

to drain out rapidly after which cold water is circulated through the chamber to reduce the milk temperature as rapidly as possible, to roughly that of the cold water supply. It is obviously desirable to remove the milk after this preliminary cooling to a refrigerator for further cooling.

The same machine is used for bottle sterilization. The bottles are first washed thoroughly then placed in the same tray carriers, but bottom side up. It is not necessary to use more than a few inches of water in the chamber since the steam which forms as the water is boiled will displace the air in the bottles and sterilize them very quickly. Exposure under this condition for twenty to thirty minutes is adequate. In some institutions, the bottles are filled with water and the chamber is filled to the overflow point, the same as when pasteurizing. This is not desirable because the water in the bottles will not heat as rapidly as that surrounding them. Sterilization will require considerably more time to no useful purpose. Very often such machines are purchased solely for bottle sterilization. In that

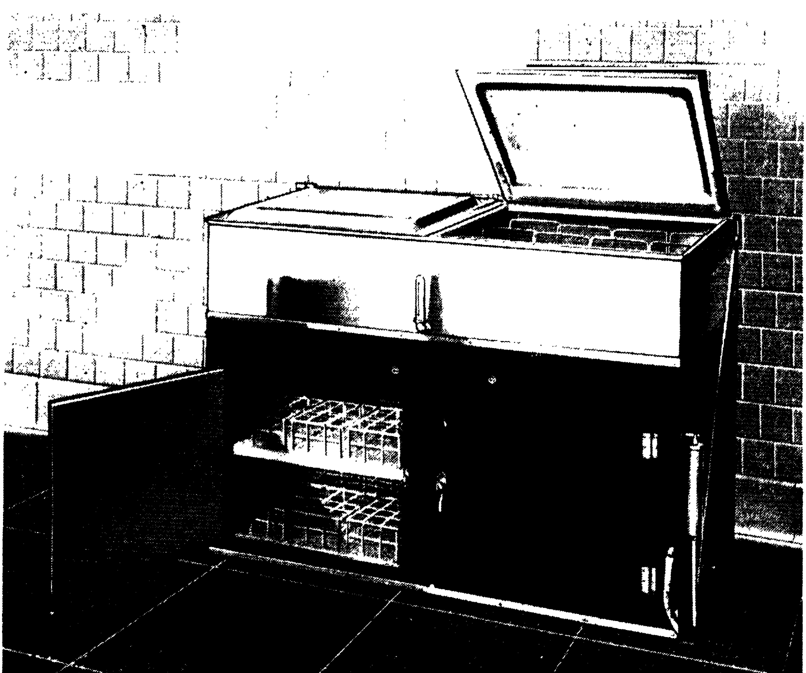

FIG. 86. 288 Bottle Pasteurizer and Bottle Sterilizer. Storage space is provided underneath for extra Tray Carriers.

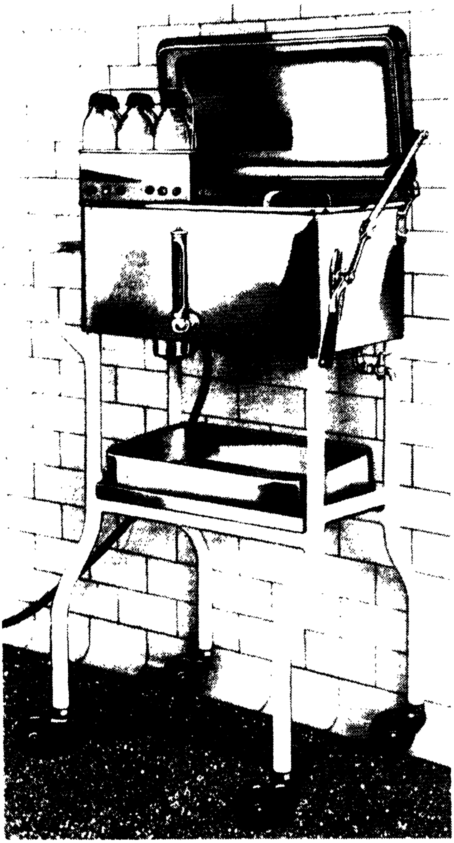

FIG. 87. Portable Electrically Heated Nursing Bottle Warmer.

event there is no purpose served in providing automatic pasteurization temperature control. The machine will be used essentially the same as an instrument or utensil boiler and will require the same type of venting.

If the machine is to be used as a pasteurizer, it should be equipped with automatic pasteurization temperature control. Such controls are now available.

The nursing bottle warmer illustrated in Fig. 87 is a most desirable unit. It has no sterilizing or pasteurization facilities but serves only to keep bottles at the proper temperature for feeding. As the feeding hour approaches, the chamber is filled with water heated to the right temperature and the bottles are put in. The machine is hooked in to the nearest wall plug and the water is held automatically at the right temperature until feeding is over.

CHAPTER XVII

Sanitary Protective Features

Very few surgical sterilizers installed prior to recent years, afford any protection whatever against contamination of water supply lines by a back flow of polluted water from the sterilizers, or against contamination of the sterilizers themselves by a back flow of foul material from the drain lines leading from the sterilizers.

These faults and methods of correcting them can best be illustrated and described by the series of diagrams which follow. Sanitary codes

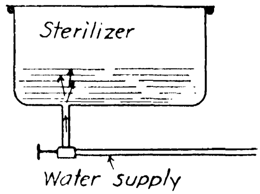

FIG. 88. How the institution's water supply can be polluted by unguarded connection to the bottoms of sterilizers which may contain polluted water.

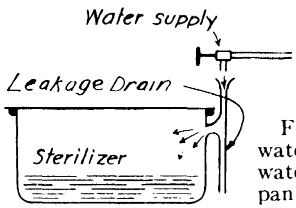

FIG. 89. The safe method of connecting supply water to any sterilizer which may contain polluted water, such as instrument or utensil sterilizers or bed-pan sterilizers.

now cover these details rather thoroughly in many large centers. In some sections these codes have been strictly enforced, and in other sections the authorities have been lax in this respect. All modern sterilizers as a rule have been designed to meet restrictive codes. There can be no doubt that these details relating to water, waste and venting connections are extremely important. Sterilizing fixtures of all types, which are improperly connected to water and waste lines, should be revamped and made to conform to safe codes. This usually can be done.

Refer to Fig. 88 and assume that the sterilizer contains soiled instruments or utensils—perhaps bedpans or urinals, and that it is being filled with water through an open valve. Should an interruption occur to the water supply by unusually heavy demand at some lower building level, or by drainage of the water riser for repairs,

polluted water from the sterilizer would drain into the supply riser. This is by no means overdrawn.

The type of water connection, Fig. 89, contains an open air-break above the top of the sterilizer. Should there be an interruption to the water supply under any condition, the vacuum formed in the supply pipe caused by its drainage will be relieved by air from the room through the open air-break. No water from the sterilizer could be drawn back. This protection is incomplete unless the opening of the air-break is sufficiently large to avoid the possibility of its being

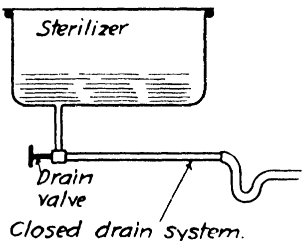

FIG. 90. How any type of surgical sterilizer can be seriously contaminated through a closed connection to the drainage system.

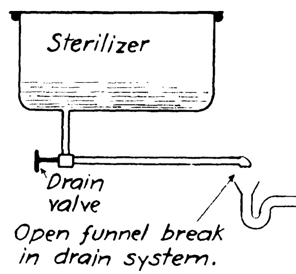

FIG. 91. A safe and thoroughly practical method of connecting the drainage line from every non-pressure (boiling type) instrument or utensil sterilizer or other sterilizer of that general type.

clogged by cleaning compounds. The air-break should occur, of course, well above the extreme top of the sterilizer.

Refer to Fig. 90. Waste valves on all surgical sterilizers are frequently left open after the sterilizer has been drained. When this occurs, if the drainage system becomes clogged, or if the pipes are too small to carry the waste from several connected fixtures, there is grave danger of back flow from the foul drain lines through the open valve direct to the sterilizer. This is particularly serious when several sterilizers or other fixtures are connected by a common small horizontal pipe leading to a larger drain riser. Very frequently such connections result in a back flow from one sterilizer to another. Often these connecting waste lines between the fixtures are not larger than ½" or ¾" pipe sizes, distinctly too small. There is no sure cure for such conditions except a thorough repiping of waste lines in larger

sizes where necessary, with the fixtures protected by an open funnel air-break as shown by figure 91.

The drainage line from the individual sterilizer need not be larger than ½″ or ¾″ pipe size, depending on the size of the sterilizer. This direct drain should be carried to a funnel type vent, Fig. 91, never smaller than 1½″ pipe size, to the line leading to other adjacent fixtures, or to the main riser. The provision of the open funnel air-break in this line between the sterilizer and its trap avoids any possibility of back flow from the drainage system to the sterilizer.

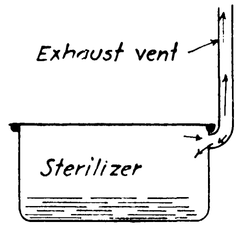

FIG. 92. How improperly connected vents or steam exhaust connections may contaminate sterilizers.

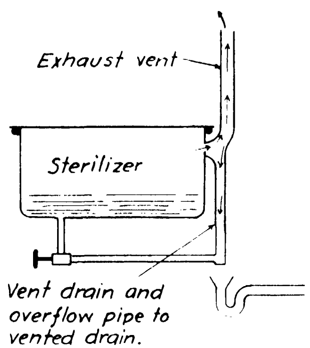

FIG. 93. How vent or steam exhaust connections should be drained to avoid contamination of the sterilizer.

Where several non-pressure sterilizers are mounted together in one group, a single open funnel can be made to protect all of the sterilizers in that group adequately, if the funnel is mounted below the bottom of the lowest sterilizer. Where such connections are made for a group of sterilizers, a single waste trap can be made to protect all of the fixtures perfectly.

There are some sterilizers still in use, notably non-pressure instrument and utensil sterilizers, which have vents connected as shown by Fig. 92. The steam escaping from the sterilizer will condense in the vent piping and drain back without restriction into the sterilizer, with seriously contaminating results.

Every vent or steam exhaust outlet from any type of sterilizer should be drained in a manner that will completely avoid this condition, as shown by figure 93.

The vent outlet immediately back of the sterilizer should have an overflow and condensation discharge drain not smaller than 1″ pipe size leading down to the open air-break funnel in the sterilizer drainage pipe. This connection as applied to non-pressure instrument or utensil sterilizers also serves as an overflow pipe to prevent the overfilling of the sterilizer should the water filling valve be left open too long.

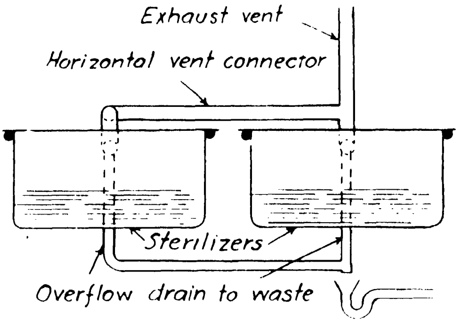

FIG. 94. Vents or steam exhaust connections from sterilizers mounted side by side should never be combined by horizontal piping as shown by this diagram. Connected as shown the exhaust steam from one sterilizer will discharge into the other sterilizer most objectionably. The proper method of interconnecting vent lines is shown by figure 95.

If the vent line from each individual sterilizer rises at a sharp angle from the outlet from the sterilizer, the exhaust steam or vapor will escape freely into the main line vent unless the size is restricted to capacities which are inadequate to carry off the vapor freely from the several fixtures.

The vent outlet from any non-pressure type surgical sterilizer should not be smaller than 2″ plumber's tubing size. The vent from

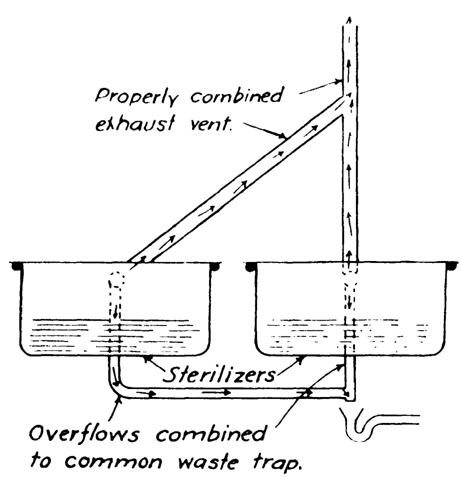

FIG. 95. How vents from two or more sterilizers side by side can be combined advantageously to a common vent riser.

each individual sterilizer should be drained immediately back of the sterilizer to prevent condensation from returning to the sterilizer, as shown by figure 93.

Condenser type steam exhaust devices, if properly connected, can be advantageously substituted for atmospheric vents.

These devices are of the ejector valve type through which a stream of cold water can be conducted exerting a slight vacuum creating effect on the sterilizer chamber, tending to draw exhaust steam or vapor into the flowing water where it is condensed and conducted to the waste system. The water connection should have the same air-break protective feature described in figure 89 to avoid pollution of the water supply line from the sterilizer. The drainage from these valves should be conducted through a connection never smaller than 1″ pipe size, to the open funnel type protected drainage connection described in figure 91.

The provision of suitable atmospheric vents for non-pressure sterilizers for instruments and utensils is frequently a very expensive item. Unless such vent lines are carried in large sizes and without the restriction of long horizontal runs, direct to atmospheric outlets, they will not function properly. The installation of condenser type exhausts under many conditions is very much less expensive. Properly installed, the condenser type exhaust functions exceptionally well.

"The device known as 'excess vapor regulator' has been developed recently to take the place of all forms of vents, for non-pressure sterilizers only. It is applicable to steam, gas or electrically heated sterilizers. It does not function as a vent at all, instead it regulates the rate of heating automatically, supplying just enough heat to keep the water boiling without creating an excess of vapor or steam to be disposed of. The device reduces water evaporation from the sterilizer to a minimum, thereby reducing scale formation on instruments, utensils and coils. It materially reduces the cost of operation (the use of power) because only enough heat is used to maintain the desired temperature. No sanitary features are involved."

Sanitary Connections to the Bedpan Washer. Bedpan and urinal devices, improperly protected, can become among the worst offenders from the sanitary standpoint. Pans filled with feces and urine are emptied in these machines and washed with cold water by means of the usual toilet flushing valve. The machines are vented to the atmosphere and waste products are discharged to the sewage system through a suitable trap. The water flushing valve should, of course, be mounted several inches above the top of the washer and some form of approved vacuum breaker should be installed between

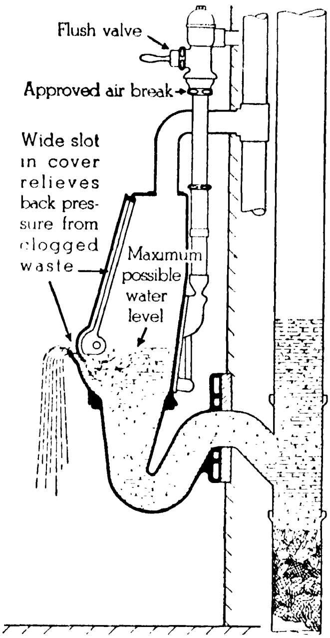

FIG. 96. The cover of this washer has no clamping lock, is loose fitting. Interior baffles prevent leakage of water from around the cover in normal usage but under abnormal conditions, in the case of clogged drain, fluid content of the chamber would overflow, could not rise appreciably above the bottom of the cover opening. Thus the vacuum breaker under the flush valve can serve its protective function, relieve vacuum in the water supply line with room air.

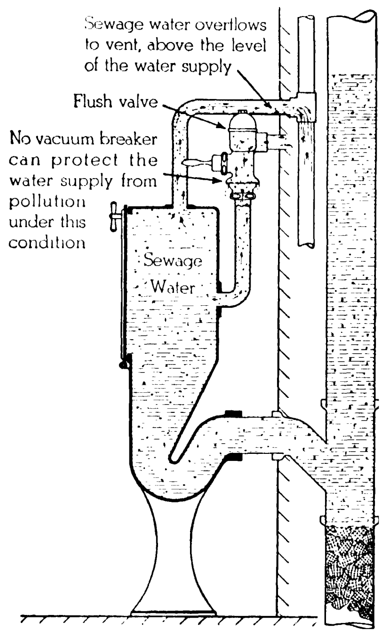

FIG. 97. The cover of this washer fits tight against a gasket. If the drain were clogged, the highly polluted fluid content of the chamber might rise to a higher level than the flush valve vacuum breaker. In that event the vacuum breaker could furnish no protection against pollution of the water supply.

the valve and the washer as indicated by Fig. 96, so that in the event of vacuum formed in the water supply line, the vacuum breaker will positively relieve the vacuum without permitting contents of the washing chamber to be drawn in.

This protection is perfectly adequate, provided the design of the chamber is such as to guard definitely against the possible rise of fluid content in the chamber to the level of the vacuum breaker under the flush valve. Fig. 96 shows a type of washing chamber in which the cover is designed with suitable baffles to prevent the normal escape of water from the chamber, but with clearance at the bottom and sides so that the water level cannot rise in the chamber materially higher than the bottom of the cover. Fig. 97 shows another type of washing chamber in which the cover closes against a gasket. In this case, a clogged waste line would permit the fluid content of the chamber to rise above the level of the flush valve. In that event, the vacuum breaker would furnish no protection whatever. Sewage could be drawn back into the water supply.

It is quite obvious that any overflow device used to prevent filling of the chamber with fluid to the level of the vacuum breaker must be adequate to discharge all the fluid that might back up from a main waste, clogged at a level below the fixture, with fluid draining down from higher levels.

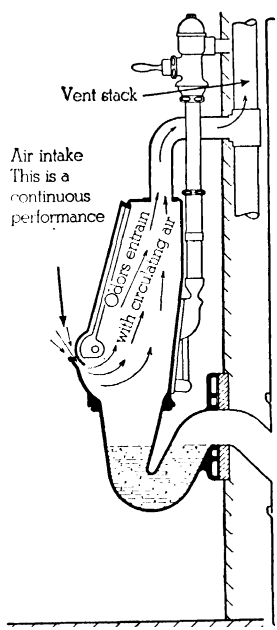

FIG. 98. Showing the aerating effect of a loose fitting cover applied to a properly vented bedpan and urinal washer.

Proper aeration of the washing and sterilizing chamber is another feature which should be considered under sanitary provisions. Fig. 98 illustrates the chimney effect of a typical washer with a loose fitting cover, vented to the atmosphere. Room air will be drawn into the chamber passing through to the vent, entraining vapor and odors. Any tight fitting cover eliminates this natural draft as indicated by Fig. 99.

Any aerating device should of course admit room air to the chamber near the bottom of the chamber to be truly effective.

Protective Waste Connections for Pressure Type Sterilizers

Waste connections from pressure sterilizers require a different type of air-break fitting than is necessary for non-pressure or boiling type sterilizers previously illustrated. The latter require protection only against the backing up of waste products which might be occasioned by a clogged line. But all pressure sterilizers are subject to rather high degrees of vacuum, necessitating air gaps in the air-break fittings sufficiently great to guard against the drawing in of waste products. It has been determined by careful tests that a ½″ pipe suspended above water vertically and subject to vacuum of 15″ will draw in the water through an air gap of 1″, but not through 1⅛″ air

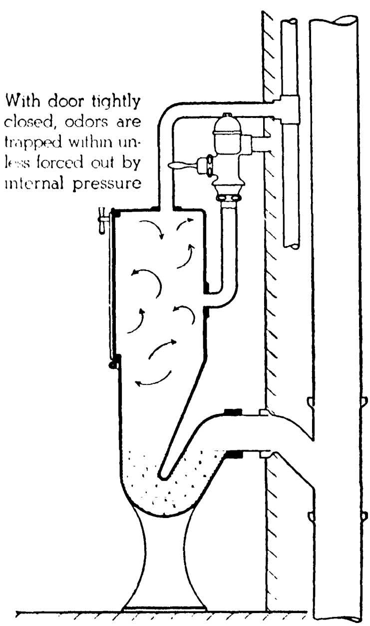

Fig. 99. A tight fitting cover traps odors and vapor within the chamber unless they are forced out by internal pressure. From the diagram it is clear that air admitted to the chamber for aeration purposes must be admitted near the bottom of the chamber to be truly effective.

gap. On the basis of this data it is considered that 1½″ air gap for all waste protective air-break fittings used on pressure sterilizers is amply protective, where the pipe size of the connection to the sterilizer does not exceed ½″. Non-pressure sterilizers in which no vacuum can possibly occur are suitably protected by air breaks in which the air gap is considerably reduced. Some city codes define what these gap limitations shall be but from a practical standpoint a gap of ½″ is perfectly adequate.

The following diagrams, Figs. 100-102, illustrate clearly how unprotected waste connections from pressure sterilizers may become dangerous. These types of sterilizers are subject to vacuum of 10″ to 20″ or more. Lacking the protection of ample air gaps in the various waste lines, foul material from the drain might easily be drawn back to the sterilizers through a possibly leaky valve. Figs. 101-103 show how protection can be provided.

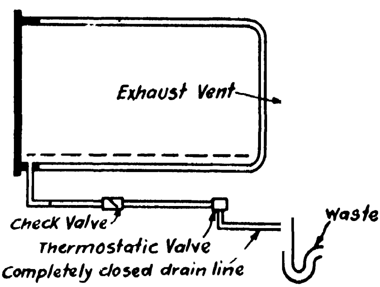

FIG. 100. A common type of surgical supply sterilizer in which the chamber is drained through a thermostatic valve direct to a combination waste and vent. A leaky check valve would permit waste products to be drawn into the chamber.

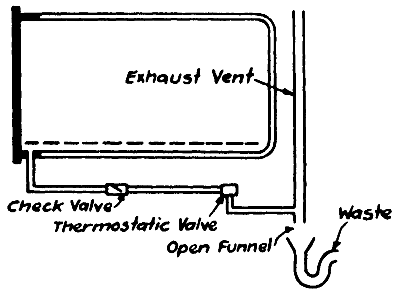

FIG. 101. The surgical supply sterilizer, Fig. 100, can be fully protected against pollution from the drain by application of an air break as shown.

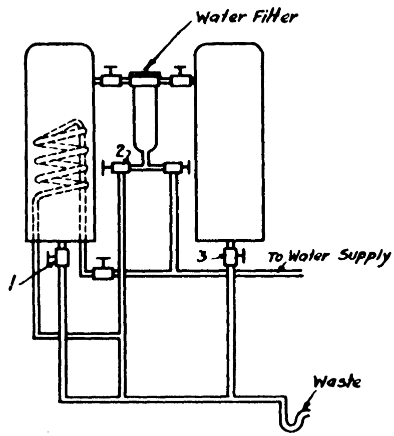

FIG. 102. A common type of water sterilizer with waste connections piped direct to the drain. Leaky valves 1, 2 or 3 would permit the reservoirs, under vacuum, to draw in waste products, or this might be occasioned by the backing up of waste products due to a clogged line.

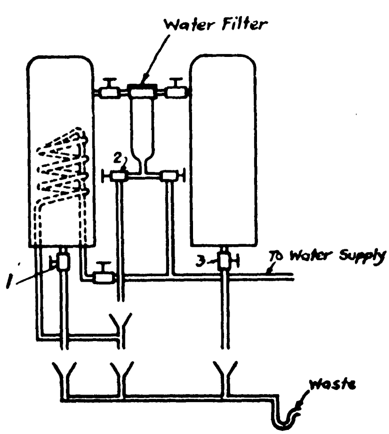

FIG. 103. Showing how air breaks can be applied to the piping, Fig. 102, to guard against pollution from the waste. Air gaps in all such connections should be 1½" or more.

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